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Emission Control Technology Division
2565 Plymouth Road
Ann Arbor, Michigan 48105

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Crankcase Emissions with Disabled PCV Systems

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by

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Contract No. 68-03-3162
Work Assignment 19

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Prepared for

ENVIRONMENTAL PROTECTION AGENCY
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FOREWORD

This project was conducted for the U.S. Environmental Protection Agency by the Department of Emissions Research of Southwest Research Institute. The project was begun in May 1984 and completed in September 1984. It was conducted under Work Assignment 19 of Contract 68-03-3162, and was identified within Southwest Research Institute as Project 03-7338-019.

Mr. Robert J. Garbe of the Emission Control Technology Division, Office of Mobile Source Air Pollution Control, Environmental Protection Agency, Ann Arbor, Michigan, served as EPA Project Officer during the early part of the project. Mr. Craig A. Harvey was named EPA Project Officer during the latter part of the project. Mr. R. Bruce Michael, of the same division, was the Branch Technical Representative. Mr. Charles T. Hare, Manager, Advanced Technology, Department of Emissions Research, Southwest Research Institute, served as the Project Manager. The project was under the supervision of Daniel A. Montalvo, Research Scientist, who served as Project Leader.

ABSTRACT

This report describes the laboratory testing of nine in-use light-duty gasoline passenger cars using up to four PCV disablement configurations. The nine vehicles included 1975 to 1983 model years, with odometer readings generally between 20,000 and 60,000 miles. No two vehicles were identical in make and engine type, and engine displacements ranged from 89 to 403 $in.^3$. The vehicles were tested over the 1975 Federal Test Procedure, with sampling for crankcase HC conducted during each individual cycle of the 3-bag FTP and during the 10-minute hot soak. Emissions of crankcase HC are provided in g/mi for the 3-bag FTP, and in g/min for the 10-minute soak.

Two PCV disablement configurations, identified as A1 and A2 in this study, contributed significant crankcase HC emissions. Disablement A1 was with the PCV valve disconnected from its orifice, but still connected to its hose going to the carburetor or manifold. The A2 disablement was like A1, but with the fresh air hose to the air cleaner completely removed. The 3-bag FTP crankcase HC emissions of the nine vehicles ranged from 0.16 to 2.72 g/mi (average 1.21 g/mi) using the A1 configuration, and from 0.71 to 4.18 g/mi (average 1.92 g/mi) using the A2 configuration. Overall, A2 hydrocarbon emissions were about 59 percent higher than A1 hydrocarbon emissions. Crankcase HC emissions with A2 disablement were two times greater than their respective Federal exhaust HC emissions standards, as averaged for eight cars. The crankcase HC emissions did not correlate strongly with odometer reading or engine displacement, although the larger-displacement engines (229 to 403 in^3) did produce most of the higher HC readings of the study. Highest crankcase HC emissions during the 10-minute soak were 0.29 and 0.19 grams per minute found with the A1 and A2 disablements, respectively. Methane was not a major constituent of crankcase emissions, the highest level detected during the FTP being 0.02 g/mi.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

The earliest form of gasoline automotive emission control was the Positive Crankcase Ventilation (PCV) System. Gasoline engines produce variable quantities of blowby gases during their operating cycle that escape past the piston rings into the crankcase. These gases contain certain unburned fuel and other pollutants that may adversely affect the environment. Since the early 1960's, most gasoline vehicles have employed a PCV system to prevent blowby gases from escaping to the atmosphere. Current EPA regulations require systems which completely eliminate the venting of crankcase emissions from gasoline-fueled vehicles. A PCV system works by routing crankcase gases into a vacuum-controlled valve (PCV valve), and then through a hose into the carburetor orifice or intake manifold, where they are subsequently burned in the combustion chamber. Fresh air to the crankcase is normally drawn through a hose connected between the valve cover and air cleaner housing.

An EPA tampering survey[1]* has indicated that crankcase emissions from some in-use light-duty gasoline passenger vehicles are uncontrolled, due to disablement of the PCV system. Approximately 2885 vehicles were randomly examined, and of these, 2.5 percent had disabled PCV systems. Although the number of vehicles with disabled PCV was low, EPA is concerned that crankcase emissions could still have a major impact on total vehicle emissions. For example, if crankcase emissions are large, then the major gasoline vehicle pollutants would be those emitted from the crankcase and not from the exhaust.

The study reported here measured crankcase HC emissions from nine in-use 1975 and later model year light-duty passenger gasoline vehicles, with four different configurations of PCV disablements. Crankcase hydrocarbon emissions were measured using normal CVS bags, as well as an on-line heated flame ionization detector (HFID). Methane analysis was also performed on the CVS bags. The dynamometer driving schedule used in the study was the 1975 3-bag Federal Test Procedure[2], but included continuous HC sampling and a fourth bag collected during the hot 10-minute soak period.

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*Superscript numbers in parentheses refer to references at the end of this report.

II. SUMMARY AND CONCLUSIONS

The major purpose of this project was to quantify crankcase HC emissions of nine in-use light-duty gasoline passenger vehicles with disabled PCV emissions control systems. Model years of the vehicles were from 1975 to 1983, with odometer readings generally from 20,000 to 60,000 miles. Engine displacements ranged from 89 to 403 $in.^3$, and no two vehicles were identical in engine type or make. Sampling of crankcase HC emissions was conducted during each cycle of the 1975 3-bag FTP Federal Test Procedure and during the 10-minute hot soak. Hydrocarbon emissions were measured using normal CVS bags as well as an on-line heated flame ionization detector (HFID). Methane analysis was also performed on the CVS bags.

Important observations and conclusions reached as a result of this project (not necessarily in order) are as follows:

- Of the four PCV disablement configurations (A1, A2, B3, and B4) evaluated in this study, only A1 and A2 were found to be significant contributors (greater than 0.1 g/mi) of crankcase HC emissions. Disablement A1 is with PCV valve disconnected from its orifice at the valve cover, and still connected to its hose going to the carburetor or manifold. The A2 disablement is like A1, but also with the fresh air hose to the air cleaner completely removed.

- Crankcase HC emissions of the nine vehicles sampled indicated levels of 0.16 to 2.72 g/mi, with an average of 1.21 g/mi, employing the A1 disablement. Hydrocarbon emissions from the crankcase using the A2 disablement averaged 1.92 g/mi and a range of 0.71 to 4.18 g/mi. Eight of the cars with A2 configuration produced an average of two times as much crankcase HC as that specified for exhaust HC in their respective Federal exhaust emissions standards.

- Meaningful correlation of crankcase HC emissions with odometer reading, engine displacement, or engine type was not evident, although the larger displacement engines (229 to 403 $in.^3$) did produce higher HC emissions (greater than 1.0 g/mi by on-line analysis). The Cougar with 351 $in.^3$ engine displacement was the highest HC emitter at 4.18 g/mi (A2), and the Tercel with 89 $in.^3$ displacement was the lowest with 0.16 g/mi (A1).

- Overall, the A2 disablement provided about half the 10-minute soak HC emissions obtained with the A1 disablement. The A1 configuration averaged 0.15 g/min HC emissions with a range of 0.00 to 0.29 g/min, while A2 varied from 0.02 to 0.19 g/min with an average value of 0.08 g/min. Highest crankcase on-line HC emitters during the 10-minute soak with A1 disablement were the Chevette and Cougar at 0.29 and 0.28 g/min, respectively. The Cougar and Skyhawk were the highest HC emitters, at 0.19 g/min, using the A2 disablement.

- Methane was not a major constituent of crankcase HC emissions, the highest level detected (from the Chevette, 98 CID) during the 3-bag FTP being 0.02 g/mi. The 3-bag FTP methane ranged from 0.41 to 1.1 percent of bag HC. No methane was detected, at a detection limit of 0.005 g/min, during the soak cycle on any vehicle.

III. TEST PLAN, VEHICLES, FUEL, AND TEST PROCEDURES

This section describes the test plan, vehicles, fuel, and test procedures. The facilities and general instrumentation are also discussed.

A. Test Plan

A copy of the Scope of Work and subsequent additions for this Work Assignment, are given in Appendix A. The intent of the test plan was to evaluate or quantify crankcase HC emissions from gasoline passenger vehicles with disabled PCV systems. Consequently, in this project, nine gasoline vehicles were actually operated. The test plan called for ten vehicles, but only nine were run because of costs incurred evaluating two added and distinct PCV disablements identified later in this discussion. The vehicles employed in the study are identified in more detail later in the report under Subsection B of Section III. For the sake of discussion in this section, however, a brief description of the vehicles with corresponding SwRI code is provided in Table 1.

TABLE 1. SUMMARY OF GASOLINE VEHICLES EVALUATED FOR CRANKCASE HYDROCARBON EMISSIONS WITH DISABLED PCV SYSTEMS

	Vehicle and Engine Description				
Vehicle Code	Year	Make	Model	Odometer Miles	Engine Displacement, ℓ/in.^{3}
01	1982	Chevrolet	Monte Carlo	20,983	3.8/229
02	1978	Mercury	Cougar	45,770	5.8/351
03	1982	Toyota	Tercel	31,875	1.5/89
04	1975	Chevrolet	Nova	58,156	4.1/250
05	1977	Buick	Skyhawk	57,234	3.8/231
06	1978	Oldsmobile	Delta 88	69,418	6.6/403
07	1983	Dodge	Aries	20,728	2.2/134
08	1978	Toyota	Celica	52,214	2.2/134
09	1978	Chevrolet	Chevette	44,139	1.6/98

The vehicles are not a statistical sample, but represent a wide range of cars. Mileages were chosen to represent typical averages instead of extremes. As specified in the test plan, no two vehicles were identical in make and engine type, and their odometer readings were generally from 20,000 to 60,000 miles. Only one vehicle, a 1978 Oldsmobile Delta 88, exceeded 60,000 miles; and it was

tested with the Project Officer's approval. Two of the test vehicles used were in each of the following displacement classes selected by the Project Officer, except for the single vehicle in the 4.0-5.6 ℓ class:

Vehicle Tested	Displacement Class
03 and 09	under 1.7 ℓ (<104 in.^{3})
07 and 08	1.8-2.5 ℓ (110-153 in.^{3})
01 and 05	2.6-3.9 ℓ (159-238 in.^{3})
04	4.0-5.6 ℓ (244-343 in.^{3})
02 and 06	greater than 5.7 ℓ (>348 in.^{3})

The basic test sequence and HC emission measurements conducted on each vehicle/PCV disablement combination were the following:

	Test Sequence (3-bag FTP and 10-minute soak)			
Emissions Measurements	Cold Transient	Cold Stabilized	Hot 10-min. Soak	Hot Transient
Continuous heated FID THC[a]	X[b]	X	X	X
CVS bag HC	X	X	X	X
CVS bag Methane	X	X	X	X

[a]THC is total hydrocarbons
[b]X indicates a sample is taken

Continuous HC was obtained during the 3-bag FTP, and also during the hot 10-minute soak. Concurrently, the normal CVS bag was obtained for each cycle including the soak. The bags were used to determine HC and methane. Emissions during the soak are reported separately from the 3-bag FTP. The analytical instrumentation for continuous THC, bag HC, and bag methane is described later in the report, in Section III, E.

Each vehicle was to be tested once over the "four-bag" FTP (as previously described for the three normal bags plus a 10-minute fourth bag sampled during the hot soak) with the following PCV configurations:

Disablements A. PCV valve disconnected from its orifice which receives crankcase emissions, and still connected to its hose going to carburetor or manifold.

Disablement A1. PCV disconnected; fresh air hose to air cleaner connected.

Disablement A2. PCV disconnected; fresh air hose to air cleaner completely removed and no part of the system plugged.

Disablements B. New disablements added

Disablement B3. PCV valve remains connected in orifice, but disconnected from hose going to carburetor or manifold; fresh air hose system intact.

Disablement B4. Fresh air hose to air cleaner completely removed; PCV system properly connected.

The new disablements (B3 and B4) were added to A1 and A2 as a technical direction by the Project Officer (See Appendix A). A schematic representation of these PCV disablements is found in Figure 1. Included in the figure are the proposed emissions sampling points. As described later in the report under Section IV, the B3 and B4 disablements were discontinued by the Project Officer after preliminary testing showed that crankcase HC emissions with these two disablements were not significant as compared to A1 and A2.

Disablement configurations A1 and A2 were each run with each vehicle, using the four-bag FTP. The Monte Carlo was the only vehicle that was run twice using the A2 disablement and "four-bag" FTP, to check the sampling system repeatability. The Monte Carlo, Cougar, and Tercel were the only cars run using the B3 and B4 disablements. Each of these three cars was run once with B3 using a cold-505 cycle, and once with B4 using a hot-505 cycle.

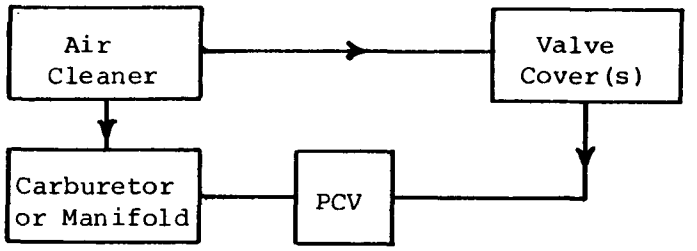
Three techniques considered early in this project to measure crankcase HC emissions included the following:

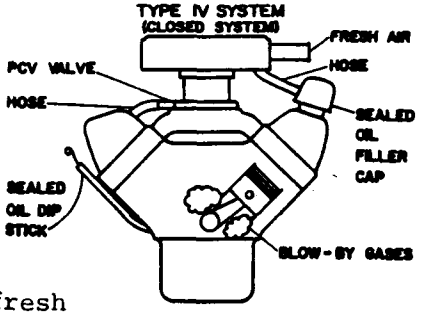
1. Measure HC concentration of gases emitted by collecting them in a bag or with a continuous FID, and determine total volume emitted separately to permit computation of mass emissions.

2. Introduce crankcase gases into a low-volume calibrated dilution system and use bag sampling, with computation similar to that used for a standard CVS to yield grams per mile.

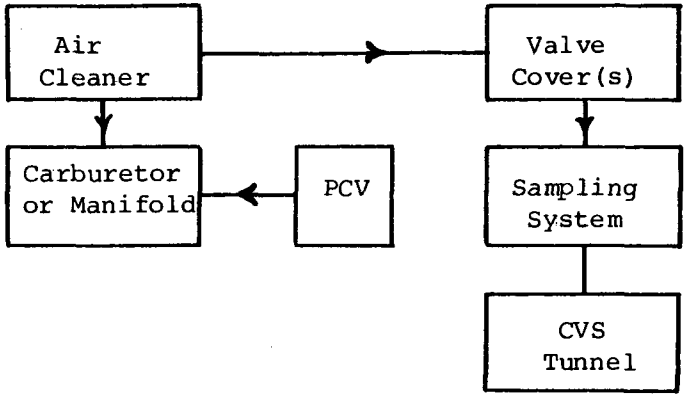
3. Introduce gases into a standard CVS dilution system, and use continuous or bag sampling to determine HC concentration, followed by standard CVS computations to yield grams per mile.

Technique No. 3 was ultimately selected because it required the least complex efforts to set-up, sample, and calculate emissions results. The technique also provided bag samples of reasonable concentration for methane analysis. The CVS system designated for use in this study is described later in this report under Section III. C.

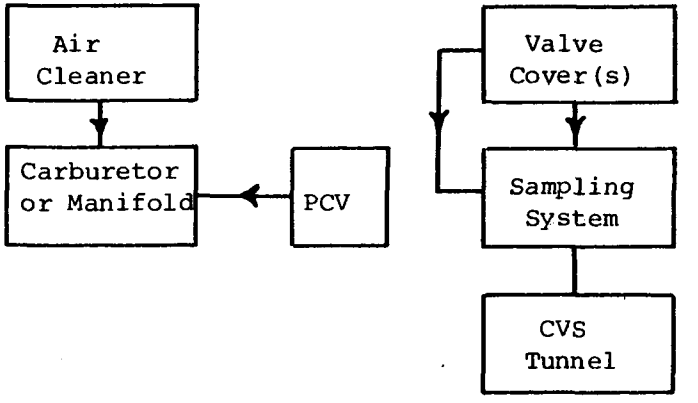




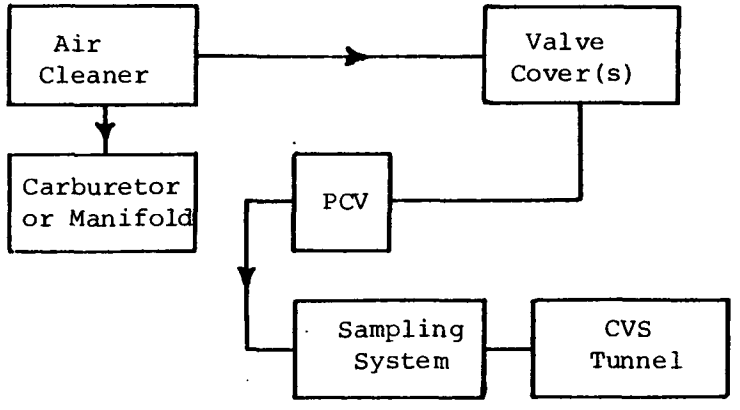
Typical PCV System with PCV and fresh air hose properly connected



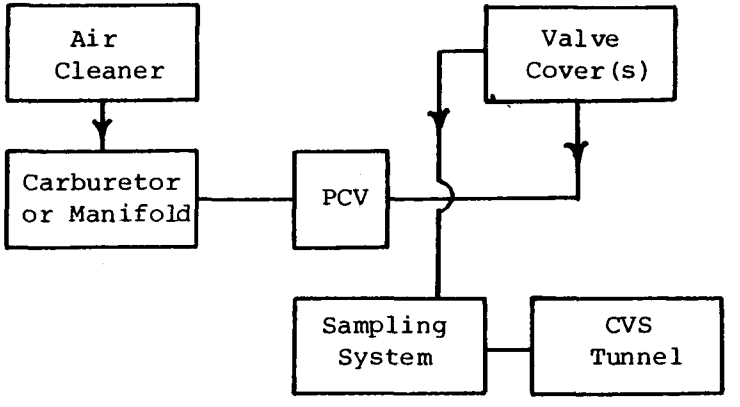
A1-Disablement Configuration with PCV disconnected; fresh air hose to air cleaner connected



A2-Disablement Configuration with PCV disconnected; fresh air hose to air cleaner completely removed and no part of the system plugged.



B3-Disablement Configuration with PCV valve connected in orifice, but disconnected from hose going to carburetor or manifold; fresh air hose system intact.



B4-Disablement Configuration with air hose to air cleaner completely removed; PCV system properly connected.

Figure 1. PCV disablement configurations with emissions sampling points

B. Test Vehicles

A request for vehicles that could become available for study in this project was issued to staff members of Southwest Research Institute and its sister organization, Southwest Foundation for Biomedical Research. A copy of the request, along with a listing of vehicles submitted by the staff members for consideration, are found in Appendix B. This list proved very helpful in enabling SwRI and the Project Officer to obtain vehicles that closely fitted the test plan vehicle constraints identified earlier in Section III. A.

A full description of the vehicles is provided in Table 2. Prior to accepting a vehicle for testing, the vehicle was run on the dyno to determine driveability, and to check for exhaust system leaks that could affect laboratory HC background. Any vehicle that had prior major engine repair, including a valve job, was disqualified from testing. The emission control system was also examined for proper connection. Of the nine vehicles tested, the Cougar, Skyhawk, and Chevette required replacement of the muffler; and no vehicle showed evidence of extreme negligence or intentional tampering with the PCV system. After the preliminary checks were found in order, the fuel tank was filled with unleaded gasoline, if needed, to a minimum three-quarter full level. Makeup oil was added to the crankcase only if the oil level was found below safe limits. During testing, only the Chevette showed a little oil leakage underneath the engine region, but no oil makeup was necessary. Views of two vehicles used in the overall 9-vehicle study are shown in Figure 2, as evaluated on the dynamometer. No significant operating difficulties were experienced with the nine cars during this project. Engine operation or response on the cars was not noticeably affected by the A1, A2 and B4 disablements; but use of the B3 disablement did produce some apparent roughness of the engines in the Monte Carlo, Cougar, and Tercel. Although not requested, a measurement of engine compression and cylinder leak-down time could have provided interesting information to explain differences in crankcase emission levels.

C. Dynamometer and CVS Sampling System

A 50 hp Clayton ECE-50 passenger car dynamometer was used for the emission testing on this project. The dynamometer has a direct-drive variable inertia system for simulation of vehicle mass from 454 kg (1000 lb) to 4082 kg (9000 lb) in 57 kg (125 lb) increments.

The constant volume sampler (CVS) used for these studies was SwRI CVS No. 3, ordinarily used for light-duty diesel applications. The diesel CVS was selected over a gasoline CVS because the former incorporates a heated probe used for on-line THC sampling by heated flame ionization detector (HFID). A 460 mm (18 in.) diameter by 5 m (16 ft) long dilution tunnel was used in conjunction with the CVS, which operated at a nominal flowrate of 9.7 m^3/min (344 cfm). This flowrate compares to 9.1 m^3/min. (320 cfm) used in the light-duty gasoline CVS system at this laboratory. A sampling interface system was prepared by SwRI for use between the normal PCV/fresh air hose orifice and the sample inlet of the dilution tunnel. The sampling interface system is described in Section III. D.

TABLE 2. DESCRIPTION OF GASOLINE TEST VEHICLES

SwRI Vehicle Code	01	02	03
Vehicle Make	Chevrolet	Mercury	Toyota
Model	Monte Carlo	Cougar	Tercel
Model Year	1981	1978	1982
Body Type	2-door	2-door	2-door
Vehicle Identification No.	1G1A237K3BR456455	8H93H697782	JT2AL25G7C4465569
Chassis Dynamometer Setting:			
Inertia, kg (lbs)	1644(3625)	2041(4500)	1021(2250)
Power, kW (hp)	7.9(10.6)	7.8(10.4)	6.0(8.0)
Engine I.D.	--	--	3A1390788
Engine Displacement (in.^{3})	3.8(229)	5.7(351)	1.5(89)
Cylinders	V8	V8	L4
Carburetion	2V	2V	2V
Emission Controls[a]	EGR/PMP/OXD/ 3CL/CAN	EGR/PMP/ OXD/CAN	EGR/PLS/OXD/ CAN
Transmission	A3	A3	M5
Tires	P195/75R14	GR78-S15	165/70-SR13
Air Conditioning	Yes	Yes	Yes
Power Steering	Yes	Yes	Yes
Power Brakes	Yes	Yes	Yes
Vehicle Odometer, km (mi)	33759(20983)	73660(45770)	51298(31875)

[a]EGR (exhaust gas recirculation), PMP (air pump), OXD (oxidation catalyst), 3CL (three-way catalyst with closed loop fuel system), CAN (carbon canister storage - evaporative emissions), PLS (pulsating air system), EFE (early fuel evaporation)

TABLE 2 (CONT'D). DESCRIPTION OF GASOLINE TEST VEHICLES

SwRI Vehicle Code	04	05	06
Vehicle Make	Chevrolet	Buick	Oldsmobile
Model	Nova	Skyhawk	Delta 88
Model Year	1975	1977	1978
Body Type	4-door	2-door	2-door
Vehicle Identification No.	LX69DJL149542	4T07A72722472	3N37K8C149929
Chassis Dynamometer Setting:			
Inertia, kg (lbs)	1814(4000)	1588(3500)	2041(4500)
Power, kW (hp)	8.9(12.0)	9.2(12.3)	10.4(14.0)
Engine I.D.	348675GM86	--	--
Engine Displacement (in.^{3})	4.1(250)	3.8(231)	6.6(403)
Cylinders	L6	V6	V8
Carburetion	1V	2V	4V
Emission Controls[a]	EGR/OXD/EFE/ CAN	EGR/OXD/ EFE/CAN	EGR/OXD/CAN
Transmission	M3	A3	A3
Tires	P185/75-14R	P165/80B13	205SR/15
Air Conditioning	No	Yes	Yes
Power Steering	No	Yes	Yes
Power Brakes	No	Yes	Yes
Vehicle Odometer, km (mi)	93593(58156)	92109(57234)	111694(69418)

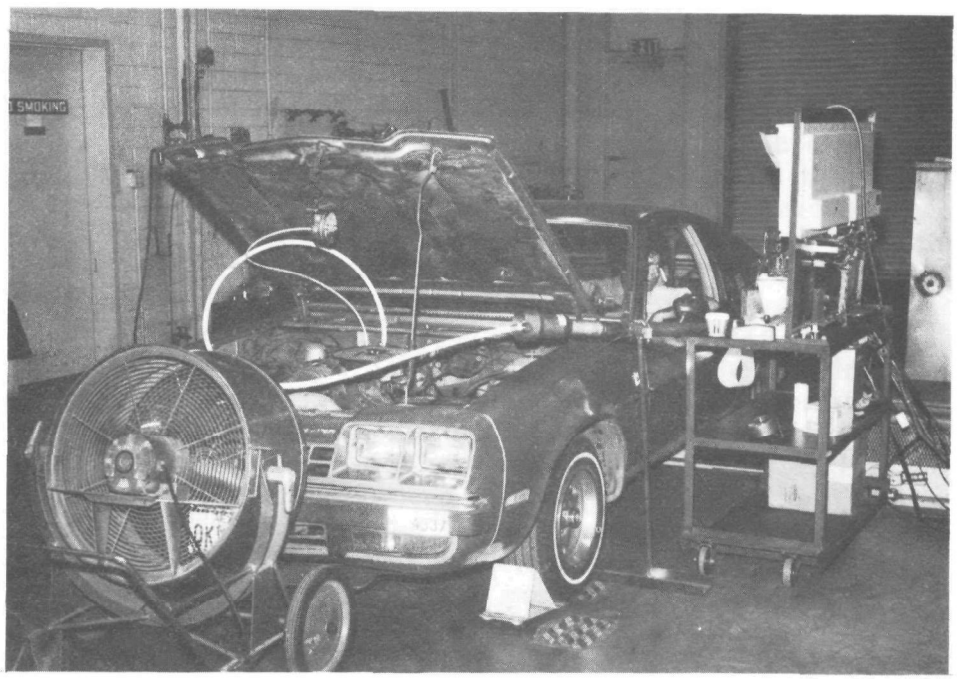
[a]EGR (exhaust gas recirculation), PMP (air pump), OXD (oxidation catalyst), 3CL (three-way catalyst with closed loop fuel system), CAN (carbon canister storage - evaporative emissions), PLS (pulsating air system), EFE (early fuel evaporation)

TABLE 2 (CONT'D). DESCRIPTION OF GASOLINE TEST VEHICLES

SwRI Vehicle Code	07	08	09
Vehicle Make	Dodge	Toyota	Chevrolet
Model	Aries	Celica	Chevette
Model Year	1983	1978	1978
Body Type	4-door	2-door	2-door
Vehicle Identification No.	1B3BD26C50C176803	RA42044389	1BD8E8Y267201
Chassis Dynamometer Setting:			
Inertia, kg (lbs)	1247(2750)	1247(2750)	1134(2500)
Power, kW (hp)	6.0(8.1)	8.1(10.9)	7.7(10.3)
Engine I.D.	--	--	
Engine Displacement (in.^{3})	2.2(134)	2.2(134)	1.6(98)
Cylinders	L4	L4	L4
Carburetion	2V	2V	1V
Emission Controls[a]	EGR/PMP/OXD/ 3CL/CAN	EGR/PMP/ OXD/CAN	EGR/OXD/CAN
Transmission	A3	M5	A3
Tires	P175/75R13)	185/70R14	155/SR13
Air Conditioning	Yes	Yes	Yes
Power Steering	Yes	Yes	No
Power Brakes	Yes	Yes	No
Vehicle Odometer, km (mi)	33371(20736)	84030(52214)	71033(44139)

[a]EGR (exhaust gas recirculation), PMP (air pump), OXD (oxidation catalyst), 3CL (three-way catalyst with closed loop fuel system), CAN (carbon canister storage - evaporative emissions), PLS (pulsating air system), EFE (early fuel evaporation)

1978 Mercury Cougar



1977 Buick Skyhawk

Figure 2. Views of gasoline vehicles as evaluated on dynamometer

D. Sampling Interface System

Two sampling interface systems were evaluated for use between the PCV/fresh air hose orifices and the CVS tunnel. Each system provides for fresh air to be drawn through it, thus not creating an unrealistic vacuum at the orifices. The two sampling systems are shown schematically in Figure 3. One system is identified as a "closed system," and the other as an "open system." Both systems were initially evaluated for proper operation in conjunction with the Monte Carlo.

The "closed system" contains a stainless steel cylindrical mixing chamber (4 in. O.D. x 6 in. long), which allows filtered makeup air, pumped out of the CVS filter box, to mix with crankcase emissions before being drawn into the tunnel via a heated (375°F) 1/2-inch Teflon line. Figure 4 provides views of the "closed system" as evaluated on the Monte Carlo. At the start of testing with the test vehicle, the sampling line at the PCV orifice is pulled out and capped, while makeup air to atmosphere and mixing chamber is simultaneously adjusted with the valve to provide a vacuum reading of 0.5 in. H_2O at the orifice. Using the "closed system" during a 2-bag FTP with the A1 PCV disablement, the tunnel draw through the small heated sample line did not sufficiently compensate for observed crankcase positive pressure increases. Concern was expressed that under these conditions, a "realistic" sampling of crankcase emissions was not occurring, and that venting of some emissions to atmosphere was likely. Therefore, no further evaluation of the "closed system" was attempted.

In the "open system," a 2-inch diameter by 16-foot long rigid stainless steel tube was prepared to reach from the tunnel to the engine compartment. The tube sampling end was extended six inches with a tube assembly that terminates at a 4-inch diameter. One end of a 5/8-inch Teflon sampling line was used to sample emissions at the PCV orifice through a rigid tube that matches the diameter of the PCV valve in order to form a close fit at the orifice. Throughout this project, either a short, rigid metal tube or a rubber hose was used at the end of the Teflon sampling line to attach snugly to the PCV and fresh air hose orifices as each engine design required. The other end of the Teflon line was inserted into the open end of the 4-inch line, thus allowing ambient makeup air to also enter the tunnel (for use in on-line HC emissions calculations, the tunnel HC background is measured as sampled at the 4-inch tube without insertion of the Teflon line). The required depth of insertion into the 4-inch opening is determined by setting the pressure gauge to 0.5 in. H_2O vacuum with the Teflon sampling line capped, and removed from the PCV orifice. The cap is removed before the line is reinserted into the PCV orifice. The Project Officer approved the continued use of the "open system" after a trial 2-bag FTP test with the A1 disablement configuration showed that tunnel draw at the 2-inch tube was sufficient to prevent crankcase emissions from escaping to atmosphere, even at positive crankcase pressures during moderate-to high-rate accels.

Testing of front-wheel-drive vehicles required that the 2-inch diameter rigid sampling tube be shortened to 8 feet in order to accommodate the open end of the tube closer to their engine compartments. The 2-inch rigid tube was shortened using two tube unions that were also used to reassemble the 16-foot

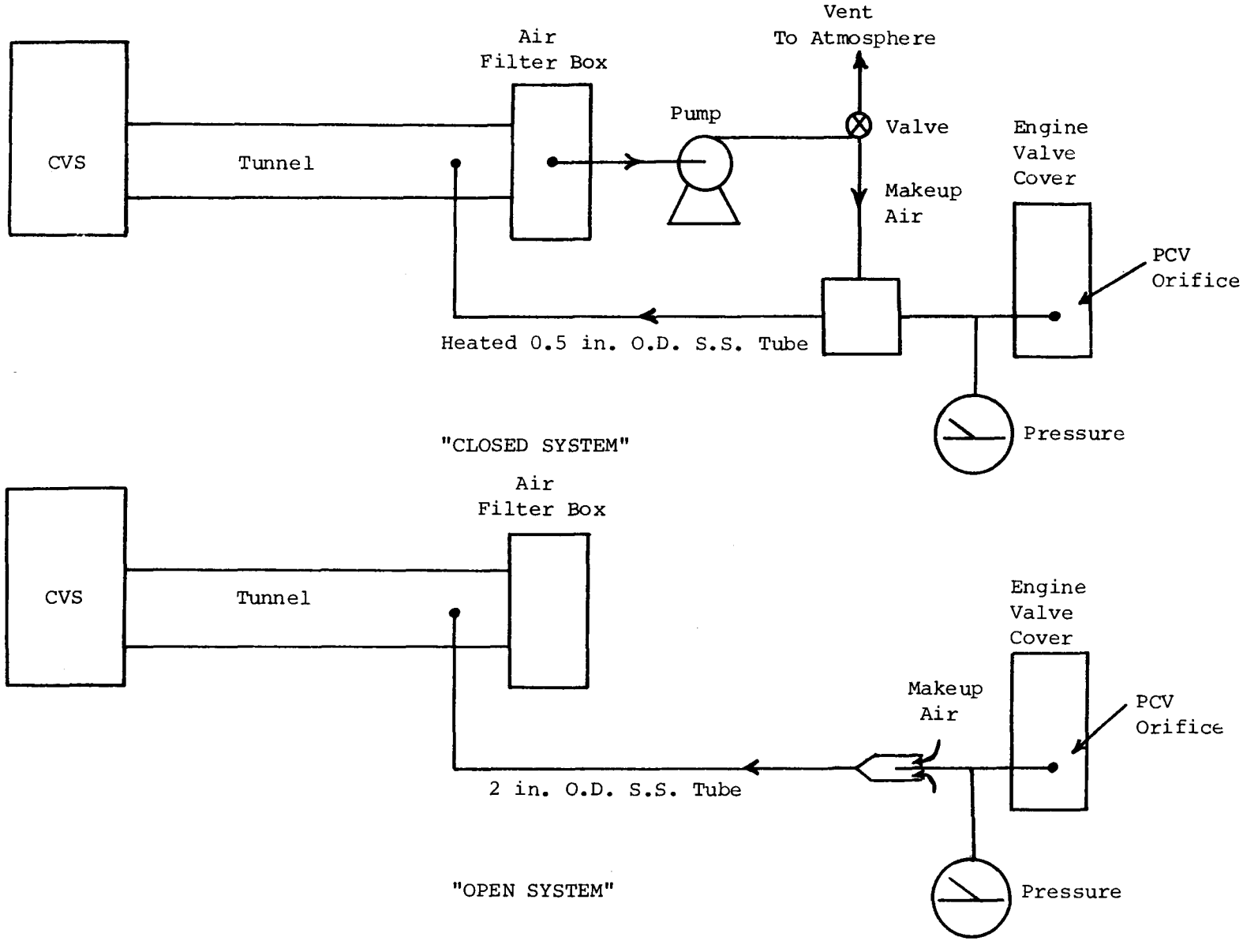


Figure 3. Sampling system interfaces for HC in gasoline crankcase gaseous emissions

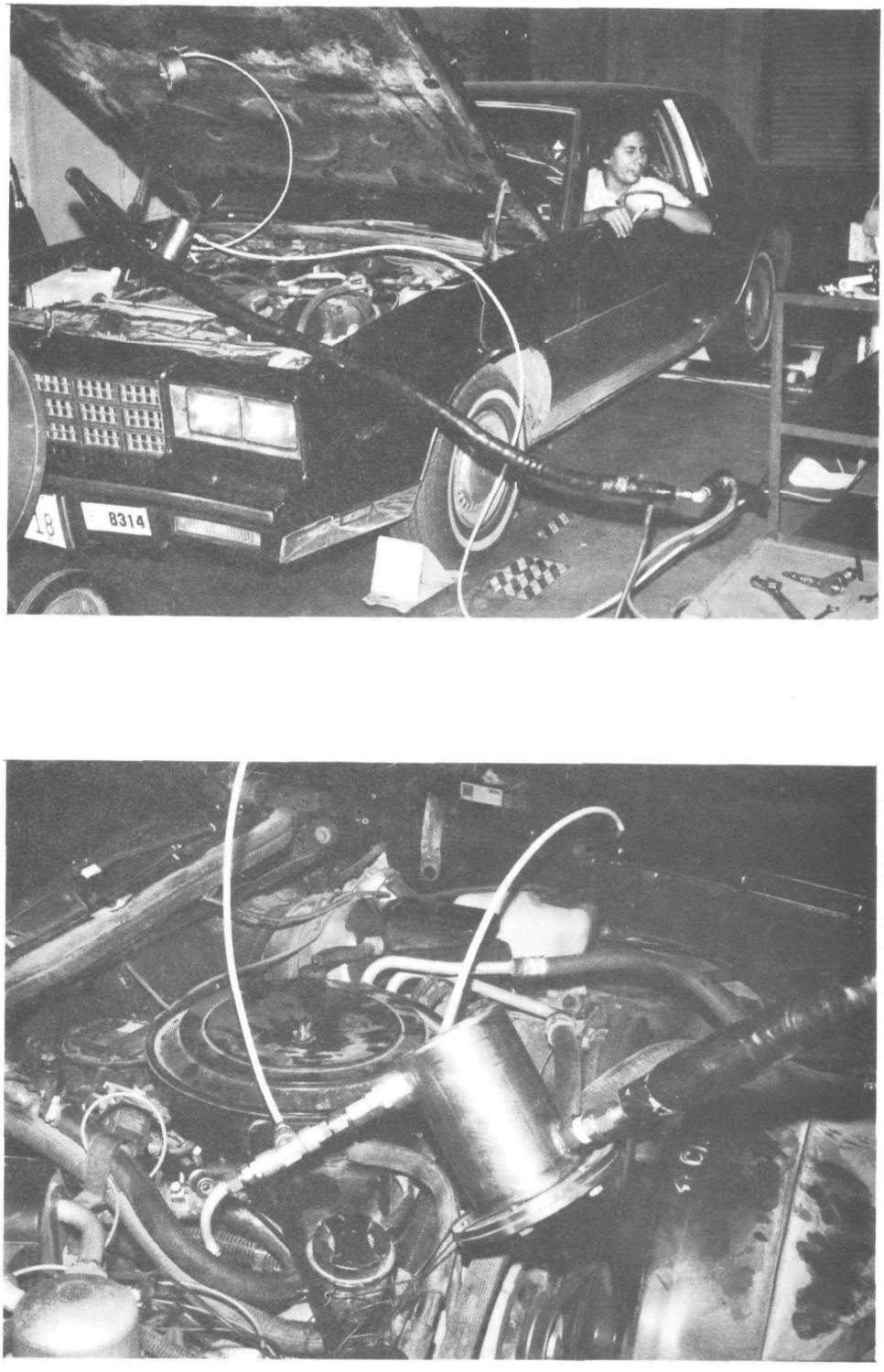


Figure 4. Views of the "closed system" as evaluated for sampling of crankcase HC using the Monte Carlo

long sampling tube configuration as needed for use with rear-wheel-drive test cars. The A2 disablement configuration also required two separate Teflon sampling lines in order to simultaneously, but separately, sample at the PCV and fresh air hose orifices as requested by the Project Officer. As with the A1 disablement, the Teflon lines were similarly inserted into the open end of the 2-inch sampling tube to a sufficient depth (approximately 6 to 8 inches) to enable setting the pressure gauge readings to 0.5 in. H_2O vacuum with sampling lines capped and removed from the orifices. Various views of the sampling interface system used on test vehicles with the A1 and A2 disablement configurations are shown in Figure 5.

E. Hydrocarbon Gaseous Emissions

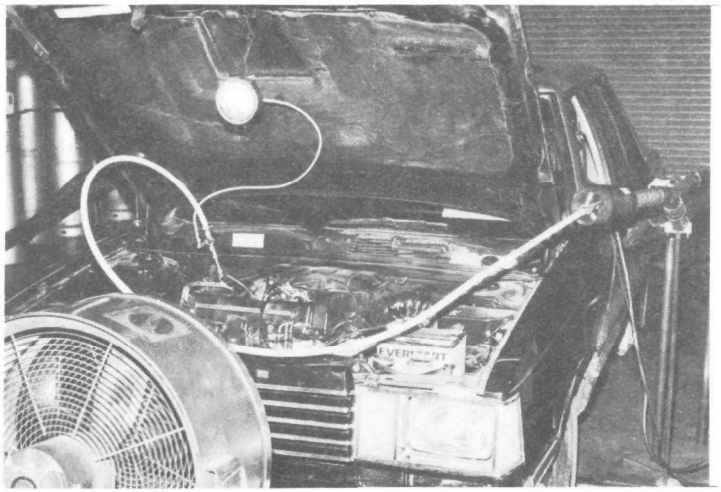
Once the crankcase emissions are introduced into the CVS tunnel; as previously explained for the sampling interface system in Section III, D., the emissions are collected and analyzed using the same procedures and equipment described in the Code of Federal Regulations[2] for regulated exhaust hydrocarbons. Hydrocarbon analysis of the sample was continuous, using a heated flame ionization detector (HFID), as is normally employed for light-duty diesel HC exhaust emissions. Electronic signal integration used with the HFID provided average dilute hydrocarbon concentration for each test cycle. The gaseous sample was taken directly from the diluted exhaust stream through a heated probe in the dilution tunnel. The gaseous emissions, as obtained in Tedlar bags at the CVS, were also analyzed for HC using the same HFID instrument employed for the on-line hydrocarbons, but with direct injection into the instrument after each 3-bag FTP test was completed. The same bags were then used to analyze for methane emissions using a GC FID procedure similar to that in the Recommended Practice SAE J1151.[3] Views of the HFID and methane analytical instruments are given in Figure 6.

F. Emission Test Procedure

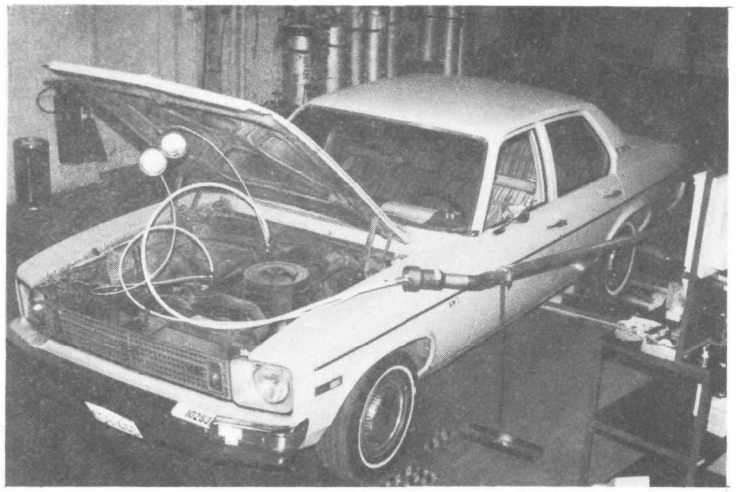
The emission test procedure utilized in this project, as briefly identified earlier in Section III. A., is further defined as follows:

> FTP - Federal Code of Regulations[2] - The FTP uses the Urban Dynamometer Driving Schedule (UDDS), which is 1372 seconds in duration. The FTP schedule is illustrated in Figure 7.

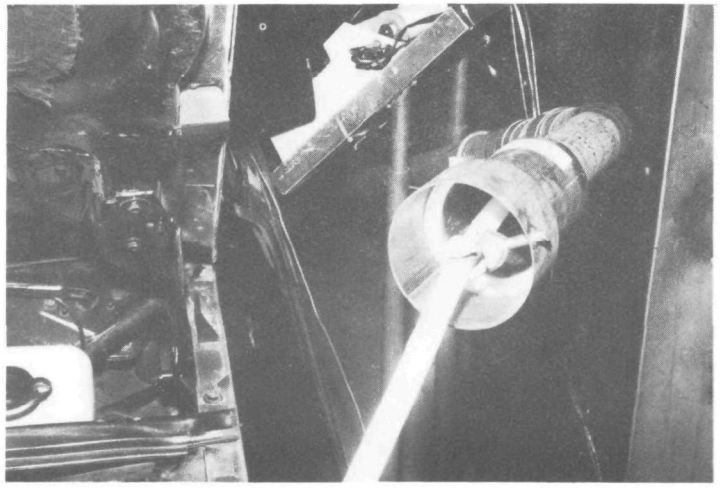
The UDDS, in turn, is divided into two segments; the first having 505 seconds and the second having 867 seconds. The FTP consists of a cold-start 505 (cold transient) and a stabilized 867 (cold stabilized), followed by a ten-minute soak and then a hot-start 505 (hot transient). In this project, crankcase emissions were also collected and measured during the 10-minute soak period in a fourth bag. The HC emissions from the fourth-bag are reported separately, i.e., not averaged in with 3-bag FTP results. A summary of the driving schedule parameters is presented in Table 3.



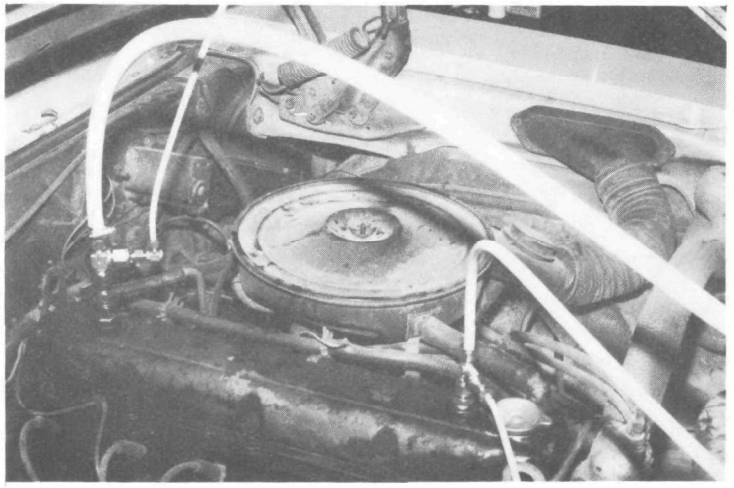
PCV Disablement (A1 Configuration)



PCV Disablement (A2 Configuration)

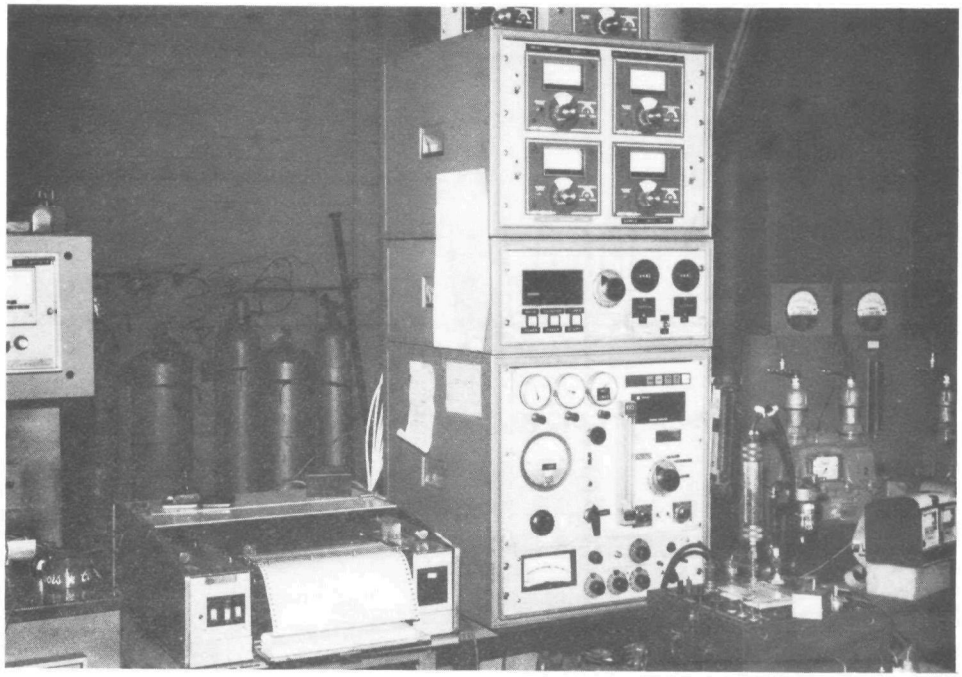


PCV Disablement (A1 Configuration)

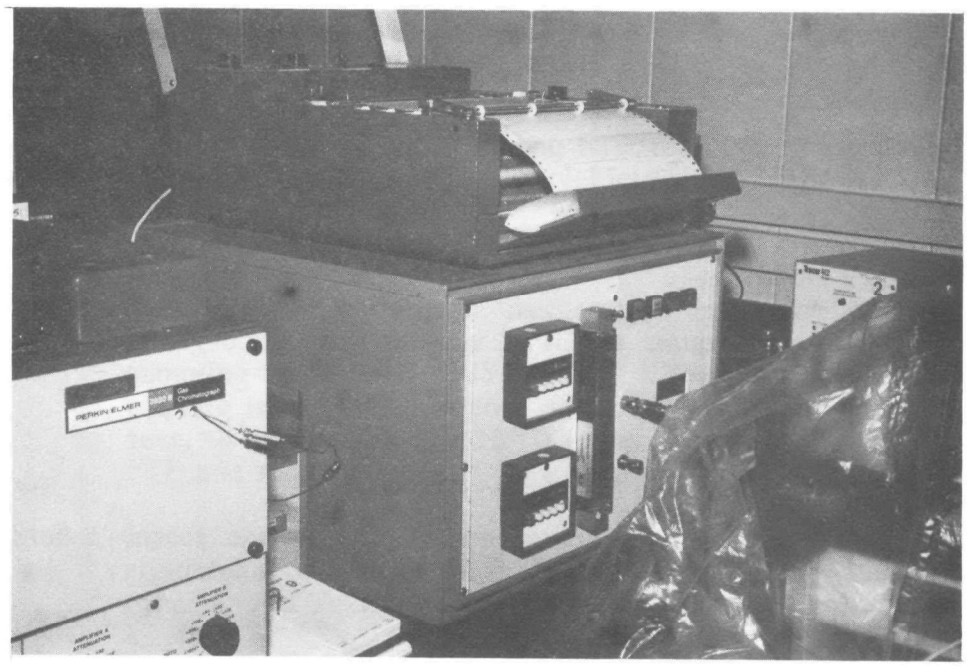


PCV Disablement (A2 Configuration)

Figure 5. Setup of sampling interface system on test vehicles with PCV disablements (A1 and A2 configurations)



Continuous and Bag HC Analyzer



Methane Analysis

Figure 6. Views of gaseous HC analytical instruments

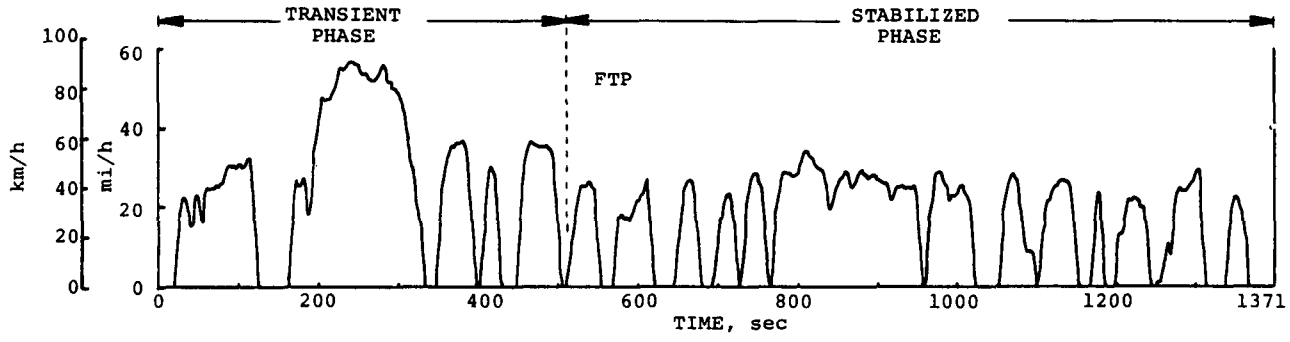


Figure 7. FTP driving cycle vs time trace

TABLE 3. SUMMARY OF DRIVING SCHEDULE PARAMETERS

Driving Schedule		Duration, Seconds	Distance, Kilometers	Average Speed km/hr	Average Speed mph
FTP:					
	Cold 505	505	5.8	41.3	25.7
	Stab 867	867	6.2	25.8	16.2
	10-min soak	600	--	--	--
	Hot 505	505	5.8	41.3	25.7

The step-sequence for running a 3-bag FTP/soak crankcase emissions test with the A1 disablement configuration on a vehicle was as follows:

Step 1 - Prep the vehicle with UDDS cycle

Step 2 - Just before cold-start next day, determine laboratory HC background with on-line HFID as sampled through rigid 2-inch sampling tube into CVS tunnel. This initial HC background reading is used with a final on-line HC background reading after test, to correct on-line HFID HC readings taken during the 3-bag FTP and soak.

Step 3 - Insert one end of Teflon sampling line into open end of 2-inch rigid tube to set tunnel draw at 0.5 in. H_2O (vacuum), with the other end of Teflon line capped and removed from PCV orifice.

Step 4 - Remove the Teflon line from the 2-inch tube. Uncap sampling end and insert into the PCV orifice.

Step 5 - Immediately upon start of cold 505 cycle, insert the Teflon line into the 2-inch tube to the required depth determined in Step 3 and secure with built-in clamp.

Step 6 - Run the 3-bag FTP and 10-minute soak in the order shown in Table 3. Continuously measure on-line HC with HFID, and obtain one CVS bag per each cycle.

Step 7 - Remove Teflon sampling line at 2-inch tube as soon as the hot 505 cycle is completed.

Step 8 - Measure final laboratory HC background with on-line HFID as was done in Step 2.

Step 9 - Measure CVS bag HC with HFID, and then bag methane with FID.

The preceding step-sequence is identical to that used with the A2 disablement configuration; but in the case of A2, one Teflon sampling line is used at the PCV orifice and another at the fresh air hose orifice in Steps 3, 4, 5, and 7.

G. Hydrocarbon Emissions Calculations

After each test and validation of correct test procedure, the crankcase HC values in: 1) integrator counts from on-line HFID; 2) ppmC from bag HFID; and 3) ppmC from the methane FID are entered into the CDC CYBER 172 computer via a data entry terminal. The emissions data are then processed according to the data reduction procedures recommended in the Code of Federal Regulations[2]. Dummy values for CO, NO_x, and CO_2 are entered in the program to permit the program to run. Fuel carbon and density values used are those specified for emissions type unleaded gasoline in the Code of Federal Regulations.[2] Separate runs are made on the computer for on-line HC, bag HC alone, and both bag HC and bag methane together. The latter calculation provides emissions results for nonmethane HC (NMHC). Crankcase HC emissions are reported in g/mi for the 3-bag FTP, and in g/min for the hot soak.

IV. GASEOUS HYDROCARBON EMISSIONS RESULTS

A discussion of the crankcase hydrocarbon emissions obtained with the nine test vehicles evaluated in this program is presented in this section. Included in this discussion is the initial study of the four PCV disablement configurations proposed for evaluation, as well as results of the "3-bag FTP plus Soak" crankcase HC emissions analyses by on-line continuous HFID, bag HFID, and bag methane FID.

A. PCV Disablement Configurations Evaluation

The proposed disablement configurations of a PCV emissions control system were identified earlier in Section III. A. as A1, A2, B3, and B4. The four configurations were evaluated with the first three cars studied, which included the Monte Carlo, Cougar, and Tercel. Crankcase HC emissions of the three cars are summarized in Table 4 along with similar emissions of the remaining six cars subsequently evaluated using only PCV disablements A1 and A2. All data in Table 4 were obtained employing the "open system" sampling interface discussed in Section III. D.

Disablement A2 was run twice with the Monte Carlo to confirm sampling system repeatability. Results in Table 4 show that emissions repeatability was adequate. Disablements B3 and B4 were not significant HC emitters (not greater than 0.01 g/mi) as measured under cold and hot FTP 505 cycles, respectively. It would appear that with B3, the PCV spring is sufficiently strong to stop vapors from reaching the sampling system (normally run at 0.5 in. H_2O vacuum). Under these conditions, the vapor may be preferentially drawn into the carburetor via the fresh air hose. In B4, the PCV correctly allows most vapors to enter the carburetor hose orifice as intended, thereby greatly limiting emissions as sampled at the fresh air hose orifice on the valve cover. Based on these results, the Project Officer requested that no further evaluation of B3 and B4 disablements be conducted, and that remaining emissions studies be conducted using only the A1 and A2 configurations.

B. Methane Analyses

Methane was not a major constituent of crankcase bag HC emissions as determined in this study. The highest methane level detected during the 3-bag FTP was 0.02 g/mi using the A2 disablement with the Chevette. Other vehicles that produced crankcase methane, but at levels not higher than 0.01 g/mi, were the Monte Carlo, Cougar, Nova, Skyhawk, Delta 88, and Aries. Overall, methane was present rather sporadically during the 3-bag FTP, with no strong trend established for its presence on a particular cycle or during the two PCV disablements. No methane was detected (at detection limit of 0.005 g/min) during the soak cycle on any vehicle.

TABLE 4. SUMMARY OF CRANKCASE HYDROCARBON EMISSIONS FROM VARIOUS VEHICLES WITH DISABLED PCV SYSTEMS

Date	Vehicle	PCV Disablement Configuration	HC Measurement	HC Emissions, g/mi				Hot Soak, g/min
				Cold Transient	Cold Stabilized	Hot Transient	3-Bag FTP	
7/10/84	Monte Carlo	A1	On-line THC	0.59	2.44	1.55	1.82	0.15
			Bag HC	0.57	2.35	1.51	1.75	0.15
			Bag Methane	0.00	0.00	0.00	0.00	0.00
7/11/84	Monte Carlo	A2	On-line THC	0.76	2.43	1.65	1.87	0.06
			Bag HC	0.76	2.34	1.54	1.80	0.05
			Bag Methane	0.00	0.00	0.00	0.01	0.00
7/17/84	Monte Carlo	A2	On-line THC	0.79	2.52	1.77	1.96	0.03
			Bag HC	0.75	2.37	1.65	1.84	0.03
			Bag Methane	0.01	0.00	0.00	0.00	0.00
Avg. of 7/11/84 & 7/17/84	Monte Carlo	A2	On-line THC	0.78	2.48	1.71	1.92	0.05
			Bag HC	0.76	2.36	1.60	1.82	0.04
			Bag Methane	0.01	0.00	0.00	0.01	0.00
7/12/84	Monte Carlo	B3	On-line THC	0.01	--	--	--	--
			Bag HC	0.00	--	--	--	--
			Bag Methane	0.00	--	--	--	--
7/12/84	Monte Carlo	B4	On-line THC	--	--	0.01	--	--
			Bag HC	--	--	0.00	--	--
			Bag Methane	--	--	0.00	--	--
7/20/84	Cougar	A1	On-line THC	0.98	3.68	2.20	2.72	0.28
			Bag HC	0.90	3.32	1.99	2.46	0.24
			Bag Methane	0.01	0.01	0.00	0.01	0.00
7/23/84	Cougar	A2	On-line THC	1.52	5.51	3.65	4.18	0.19
			Bag HC	1.46	5.03	3.43	3.86	0.20
			Bag Methane	0.01	0.00	0.01	0.00	0.00
7/24/84	Cougar	B3	On-line THC	0.00	--	--	--	--
			Bag HC	0.00	--	--	--	--
			Bag Methane	0.00	--	--	--	--

TABLE 4 (CONT'D). SUMMARY OF CRANKCASE HYDROCARBON EMISSIONS FROM VARIOUS VEHICLES WITH DISABLED PCV SYSTEMS

Date	Vehicle	PCV Disablement Configuration	HC Measurement	HC Emissions, g/mi				Hot Soak, g/min
				Cold Transient	Cold Stabilized	Hot Transient	3-Bag FTP	
7/24/84	Cougar	B4	On-line THC	--	--	0.00	--	--
			Bag HC	--	--	0.01	--	--
			Bag Methane	--	--	0.00	--	--
7/26/84	Tercel	A1	On-line THC	0.05	0.23	0.10	0.16	0.06
			Bag HC	0.05	0.25	0.12	0.17	0.06
			Bag Methane	0.00	0.00	0.00	0.00	0.00
7/27/84	Tercel	A2	On-line THC	0.32	0.92	0.60	0.71	0.04
			Bag HC	0.31	0.91	0.60	0.70	0.05
			Bag Methane	0.00	0.00	0.00	0.00	0.00
7/30/84	Tercel	B3	On-line THC	0.00	--	--	--	--
			Bag HC	0.00	--	--	--	--
			Bag Methane	0.00	--	--	--	--
7/30/84	Tercel	B4	On-line THC	--	--	0.00	--	--
			Bag HC	--	--	0.00	--	--
			Bag Methane	--	--	0.00	--	--
8/1/84	Nova	A1	On-line THC	0.23	1.52	0.89	1.08	0.10
			Bag HC	0.24	1.51	0.84	1.06	0.08
			Bag Methane	0.00	0.01	0.00	0.00	0.00
8/2/84	Nova	A2	On-line THC	0.81	2.09	1.56	1.68	0.04
			Bag HC	0.74	1.98	1.49	1.59	0.06
			Bag Methane	0.00	0.01	0.00	0.01	0.00
8/7/84	Skyhawk	A1	On-line THC	0.69	2.39	1.46	1.79	0.18
			Bag HC	0.59	2.22	1.39	1.66	0.17
			Bag Methane	0.00	0.00	0.00	0.00	0.00
8/8/84	Skyhawk	A2	On-line THC	0.85	2.90	1.76	2.16	0.19
			Bag HC	0.71	2.63	1.64	1.96	0.19
			Bag Methane	0.00	0.01	0.00	0.00	0.00

TABLE 4 (CONT'D). SUMMARY OF CRANKCASE HYDROCARBON EMISSIONS FROM VARIOUS VEHICLES WITH DISABLED PCV SYSTEMS

Date	Vehicle	PCV Disablement Configuration	HC Measurement	HC Emissions, g/mi				Hot Soak, g/min
				Cold Transient	Cold Stabilized	Hot Transient	3-Bag FTP	
8/9/84	Delta 88	A1	On-line THC	0.42	2.11	0.94	1.45	0.15
			Bag HC	0.41	2.02	0.89	1.38	0.14
			Bag Methane	0.01	0.00	0.00	0.00	0.00
8/10/84	Delta 88	A2	On-line THC	1.14	3.23	2.16	2.51	0.03
			Bag HC	1.12	3.07	2.01	2.38	0.04
			Bag Methane	0.01	0.00	0.00	0.01	0.00
8/14/84	Aries	A1	On-line THC	0.36	1.43	0.97	1.08	0.00
			Bag HC	0.36	1.39	0.94	1.05	0.03
			Bag Methane	0.01	0.00	0.00	0.00	0.00
8/15/84	Aries	A2	On-line THC	0.40	1.44	0.99	1.10	0.05
			Bag HC	0.35	1.39	0.93	1.05	0.01
			Bag Methane	0.00	0.00	0.00	0.00	0.00
8/17/84	Celica	A1	On-line THC	0.11	0.90	0.32	0.57	0.10
			Bag HC	0.08	0.79	0.33	0.52	0.08
			Bag Methane	0.00	0.00	0.00	0.00	0.00
8/20/84	Celica	A2	On-line THC	0.32	1.04	0.78	0.82	0.02
			Bag HC	0.28	0.98	0.73	0.77	0.05
			Bag Methane	0.00	0.00	000	0.00	0.00
8/22/84	Chevette	A1	On-line THC	0.04	0.33	0.11	0.21	0.29
			Bag HC	0.03	0.29	0.16	0.20	0.25
			Bag Methane	0.01	0.00	0.00	0.00	0.00
8/23/84	Chevette	A2	On-line THC	0.79	2.98	1.63	2.16	0.07
			Bag HC	0.60	2.62	1.43	1.88	0.09
			Bag Methane	0.02	0.01	0.01	0.02	0.00

In an earlier EPA study[4] of 1970 model year non-catalyst light-duty gasoline passenger cars, SwRI determined that exhaust HC emissions contained from 3.6 to 6.8 percent (average 4.8 percent) methane. The 3-bag FTP methane levels in the crankcase in Table 4, by comparison, were 0.41 to 1.1 percent of bag HC. Excluding the Chevette cold transient methane results, individual cycles of the FTP produced methane in the range of 0.29 to 3.3 percent bag HC.

C. Crankcase On-Line and Bag HC Emissions

Crankcase HC emissions results in Table 4, determined on the 3-bag FTP using on-line and bag HFID analyses, are illustrated in Figures 8 and 9 for PCV disablements A1 and A2. respectively. Included in the figures are the Federal HC Emissions Standards for light-duty passenger vehicle exhaust emissions which are 1.5 g/mi for model years 1975 through 1979, and 0.41 g/mi for model years 1980 to present.

Figures 8 and 9 indicate that the 3-bag FTP on-line HC was generally higher than bag HC throughout the study. The A1 disablement with the Tercel was the only time where 3-bag FTP bag HC was higher than on-line HC, and that only by 6 percent or 0.01 g/mi. On-line HC ranged from one to 13 percent (overall average 6 percent) higher than bag HC. The four vehicles showing larger differences than 7 percent between 3-bag FTP on-line and bag HC were the Cougar with A1 (10 percent or 0.26 g/mi) and A2 (8 percent or 0.32 g/mi), Skyhawk with A2 (9 percent or 0.20g/mi), Celica with A1 (9 percent or 0.05 g/mi), and Chevette with A2 (13 percent or 0.28 g/mi).

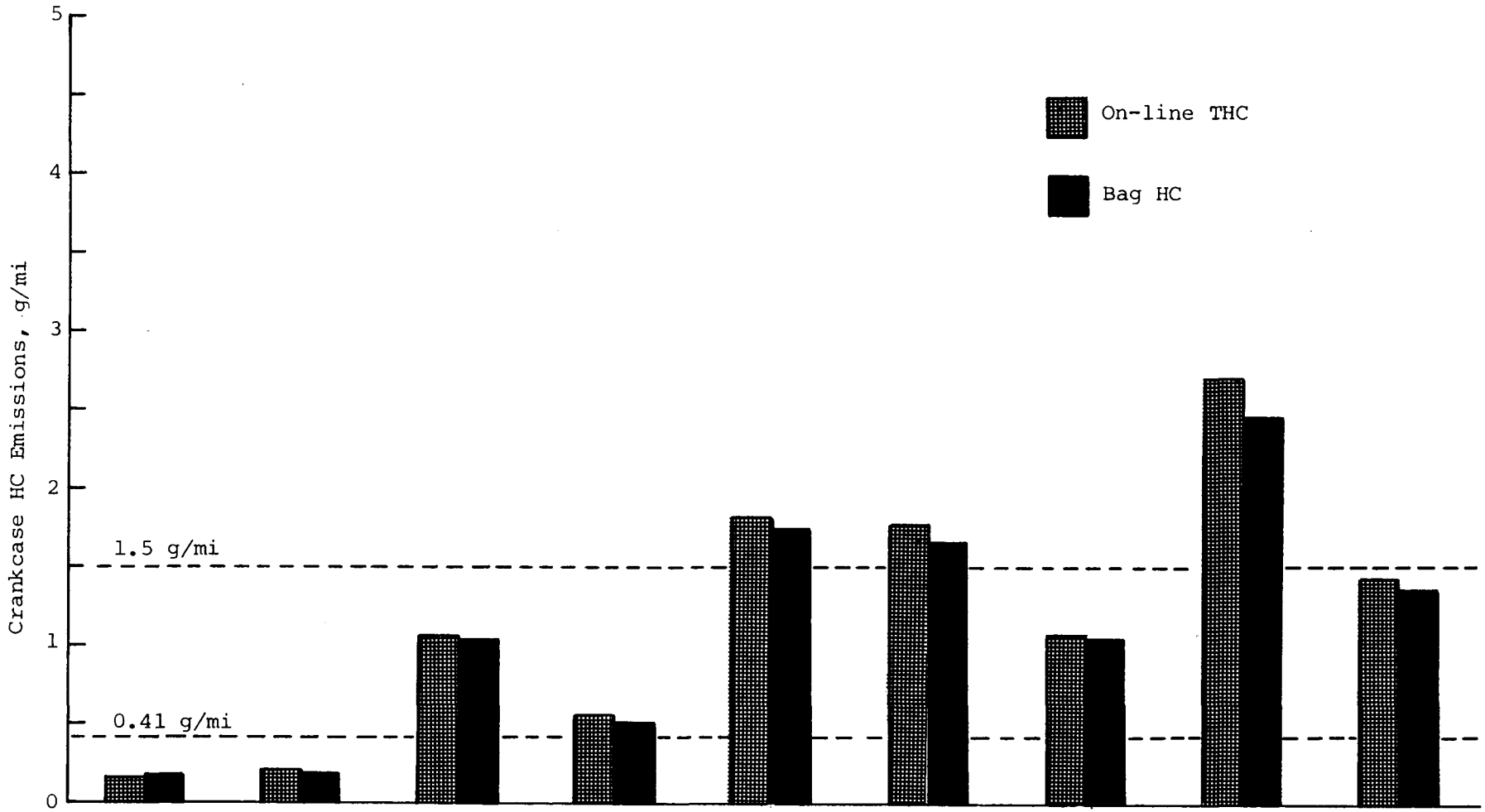
Results for individual cycles of the 3-bag FTP in Table 4 also indicate the tendency of on-line HC to exceed bag HC. The average difference of on-line HC over bag HC was 8 percent. In a few cycles (Tercel-A1 and Nova-A1), where bag HC was higher than on-line HC, the differences averaged 11 percent, which translates to only about 0.02 g/mi.

On-line and bag HC readings during soak were generally similar, with four tests showing equal readings. Nine tests had higher on-line HC than bag HC, while seven tests had higher bag HC than on-line HC. However, all of the differences between on-line and bag HC were within 0.04 g/min.

Since this study has shown that on-line HC is generally higher than bag HC, subsequent discussions of crankcase emissions in this report will employ only the on-line HC data for ease of comparison between different PCV disablements during the 3-bag FTP and soak.

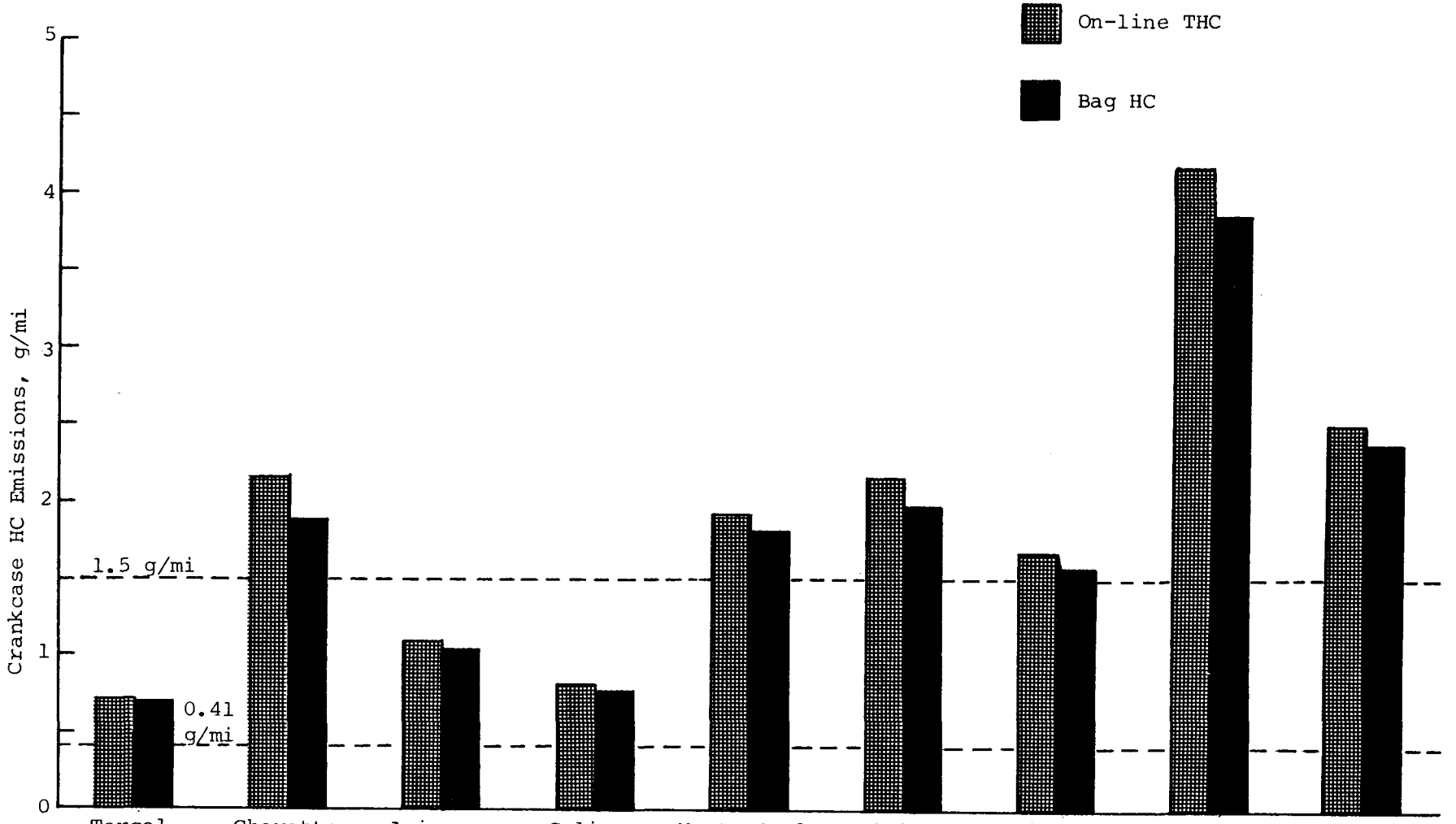
D. FTP Crankcase On-Line HC Emissions

Crankcase on-line HC emissions on the 3-bag FTP with the nine cars, as shown in Table 4, are compared to Federal exhaust HC emission standards for the same models in the following summary:



Vehicle	Tercel	Chevette	Aries	Celica	Monte Carlo	Skyhawk	Nova	Cougar	Delta 88
Year	1982	1978	1983	1978	1982	1977	1975	1978	1978
Odometer,mi	32K	44K	21K	52K	21K	57K	58K	46K	69K
Eng.Disp.,$in.^3$	89	98	134	134	229	231	250	351	403
Eng.Type	L4	L4	L4	V6	V6	V6	L6	V8	V8

Figure 8. Crankcase HC emissions of nine test vehicles during 3-bag FTP with PCV disablement configuration A1.



Vehicle	Tercel	Chevette	Aries	Celica	Monte Carlo	Skyhawk	Nova	Cougar	Delta 88
Year	1982	1978	1983	1978	1982	1977	1975	1978	1978
Odometer, mi	32K	44K	21K	52K	21K	57K	58K	46K	69K
Eng.Disp.,$in.^3$	89	98	134	134	229	231	250	351	403
Eng.Type	L4	L4	L4	L4	V6	V6	L6	V8	V8

Figure 9. Crankcase HC emissions of nine test vehicles during 3-bag FTP with PCV disablement configuration A2

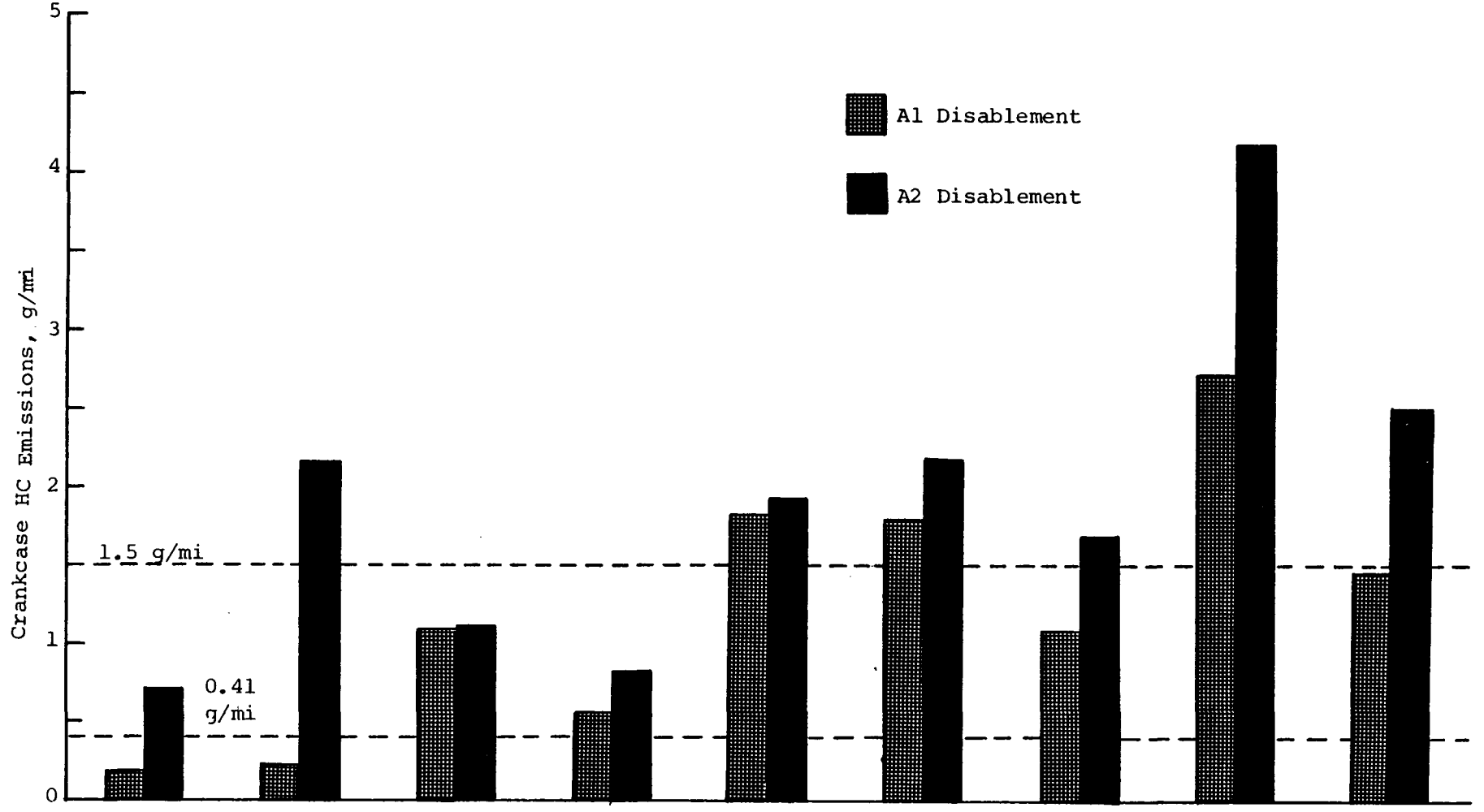
Vehicle	3-bag FTP Federal Exhaust HC Emissions Standard, g/mi	3-bag FTP Crankcase On-Line HC Emissions, g/mi PCV Disablement A1	A2
Monte Carlo	0.41	1.82	1.92
Cougar	1.5	2.72	4.18
Tercel	0.41	0.16	0.71
Nova	1.5	1.08	1.68
Skyhawk	1.5	1.79	2.16
Delta 88	1.5	1.45	2.51
Aries	0.41	1.08	1.10
Celica	1.5	0.57	0.82
Chevette	1.5	0.21	2.16
	Average	1.21	1.92

Cars with crankcase HC emissions exceeding their respective Federal exhaust HC emission standards included the Monte Carlo (A1 and A2), Cougar (A1 and A2), Tercel (A2), Nova (A2), Skyhawk (A1 and A2), Delta 88(A2), Aries (A1 and A2), and Chevette (A2). Most cars showed higher crankcase emissions than the 0.41 g/mi (Federal Exhaust HC Emissions Standard for 1980 to present), with A1 showing 1.4 to 6.6 times this limit and A2 showing 1.7 to 10 times the standard. The Tercel and Chevette with the A1 disablement were the only two cases for which crankcase emissions did not surpass the 0.41 g/mi standard.

In all cases, the A2 disablement produced higher HC emissions than the A1 disablement. Excluding the Tercel and Chevette, the remaining seven vehicles produced from 5.5 to 73 percent more HC with A2 than with A1. The Tercel and Chevette emitted more than four times as much HC with A2 than with A1. Vehicles showing more than 50 percent HC increase from A1 to A2 disablement were the Cougar (54 percent), Tercel (100 percent), Nova (56 percent), Delta 88 (73 percent) and Chevette (100 percent). The finding that the A2 disablement HC emissions are generally higher than those with the A1 disablement is as might be expected, since blowby emissions should be more readily emitted from the crankcase through two open orifices on the valve cover rather than one.

Results of crankcase on-line hydrocarbon emissions with PCV disablement configuration A1 and A2 on the nine test vehicles are shown graphically in Figure 10. Although a correlation of HC emissions with odometer mileage or engine displacement is not easily discernable, the graph does show on closer study that the larger displacement engines (229 $in.^3$ and larger) produced most of the higher crankcase HC emissions. Engines in this displacement range all had HC emissions rates greater than 1.0 g/mi. Moreover, the Monte Carlo (229 $in.^3$), Skyhawk (231 $in.^3$),and Cougar (351 $in.^3$) had HC emissions greater than 1.5 g/mi using both disablements. The Nova (250 $in.^3$) and Delta 88 (403 $in.^3$) also had HC levels greater than 1.5 g/mi, but only with the A2 disablement.

The Cougar with the 351 $in.^3$ engine displacement produced the highest HC emissions of the study, indicating 2.72 g/mi with A1 disablement and 4.18 g/mi with A2 disablement. The smallest engine displacement studied in this



Vehicle	Tercel	Chevette	Aries	Celica	Monte Carlo	Skyhawk	Nova	Cougar	Delta 88
Year	1982	1978	1983	1978	1982	1977	1975	1978	1978
Odometer, mi	32K	44K	21K	52K	21K	57K	58K	46K	69K
Eng.Disp.,in.^{3}	89	98	134	134	229	231	250	351	403
Eng.Type	L4	L4	L4	L4	V6	V6	L6	V8	V8

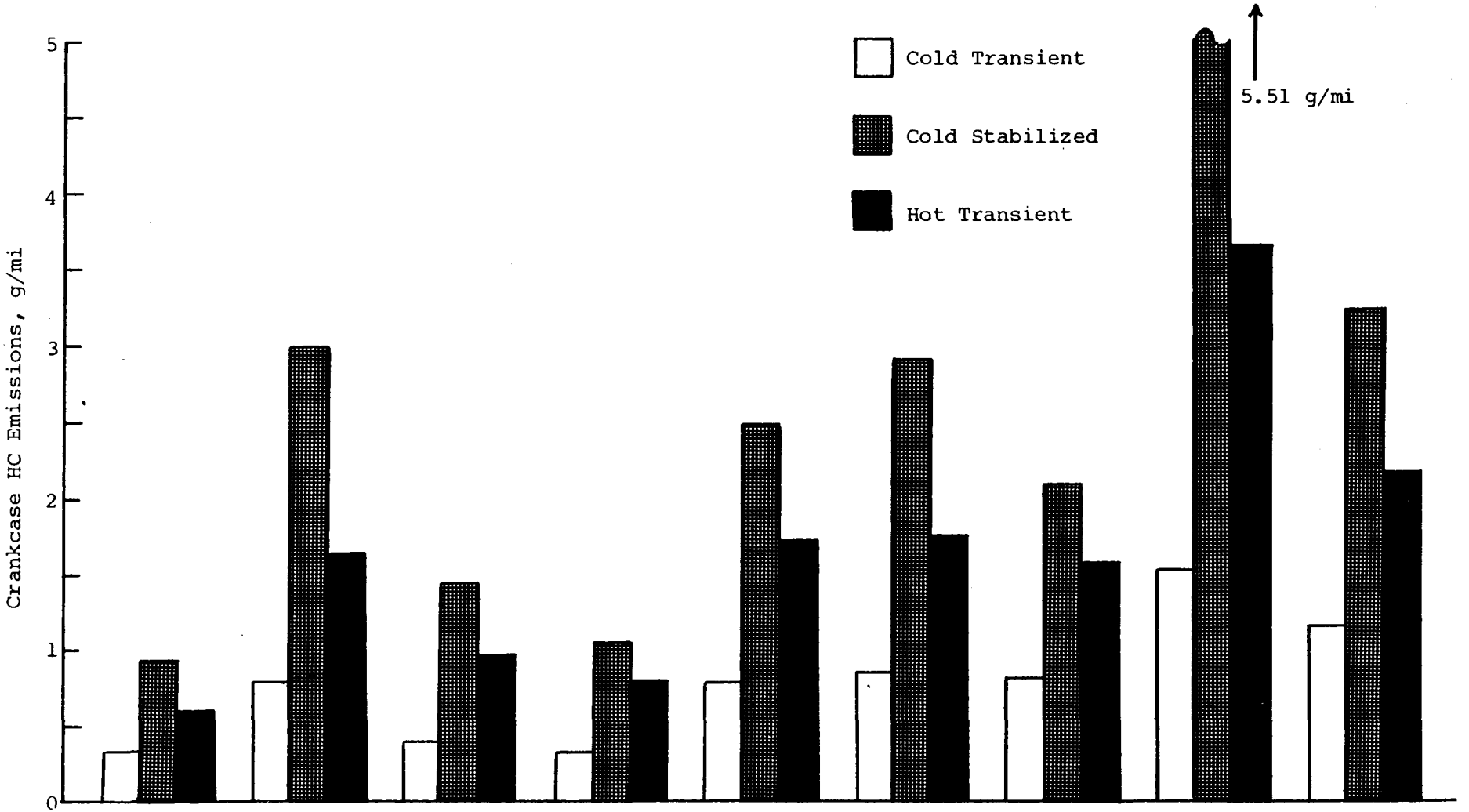
Figure 10. Crankcase on-line THC emissions of nine vehicles during 3-bag FTP with PCV disablement configurations A1 and A2

program, also produced the lowest A1 and A2 disablement HC emissions overall. This engine in the Tercel, with an 89 $in.^3$ displacement, produced crankcase HC emissions of 0.16 g/mi with A1 disablement, and 0.71 g/mi with A2 disablement. The Chevette, with 98 $in.^3$ displacement, had the second lowest (0.21 g/mi) HC emissions with the A1 disablement, but also the highest (2.16 g/mi) HC emissions with the A2 disablement of the 89 to 134 $in.^3$ engines.

During this study, methylene chloride washings of the Teflon tube and 2-inch rigid tube sampling system were conducted after some of the 3-bag FTP crankcase emissions tests (the sampling system was also cleaned and dried prior to testing). The washings were concentrated in weighing vials and dried under nitrogen gas. Dried weights of the concentrate indicated that HC losses in the sampling system were insignificant, since they constituted only two percent or less of the respective crankcase emissions as determined during the 3-bag FTP. Some of the concentrates were oily in appearance.

Crankcase HC emissions measured during individual cycles of the 3-bag FTP tests with the nine vehicles were summarized in Table 4. Illustrated in Figure 11 are the on-line HC results from Table 4, taken during the cold transient, cold stabilized, and hot transient cycles using the A2 disablement configuration of the PCV system. The data clearly indicate that the cold transient and cold stabilized cycles, respectively, showed the lowest and highest HC levels for each vehicles throughout the study. Not only did the three cycles emit HC in a regular pattern, but they also showed a consistent relationship of HC levels between them on each vehicle. This relationship is more clearly demonstrated by listing the ratio of the cold stabilized and hot transient HC emissions to cold transient HC emissions for each vehicle, as summarized below:

Vehicle	Ratio of Cold Stabilized HC to Cold Transient HC	Ratio of Hot Transient HC to Cold Transient HC
Monte Carlo	3.2	2.2
Cougar	3.6	2.4
Tercel	2.9	1.9
Nova	2.6	1.9
Skyhawk	3.4	2.1
Delta 88	2.8	1.9
Aries	3.6	2.5
Celica	3.3	2.4
Chevette	3.8	2.1
Avg.	3.2	2.2
Std. Dev.	0.41	0.24



Vehicle	Tercel	Chevette	Aries	Celica	Monte Carlo	Skyhawk	Nova	Cougar	Delta 88
Year	1982	1978	1983	1978	1982	1977	1975	1978	1978
Odometer, mi	32K	44K	21K	52K	21K	57K	58K	46K	69K
Eng.Disp.,in.^{3}	89	98	134	134	229	231	250	351	403
Eng.Type	L4	L4	L4	L4	V6	V6	L6	V8	V8

Figure 11. Crankcase on-line THC emissions of nine vehicles during individual cycles of 3-bag FTP with PCV disablement configuration A2

The ratio of cold stabilized HC to cold transient HC for the nine cars ranged from 2.6 (Nova) to 3.8 (Chevette), with an average of 3.2 and standard deviation of 0.41. Similarly, ratios of the hot transient HC to cold transient HC varied from 1.9 (Tercel, Nova, and Delta 88) to 2.5 (Aries), and averaged 2.2 with a standard deviation of 0.24.

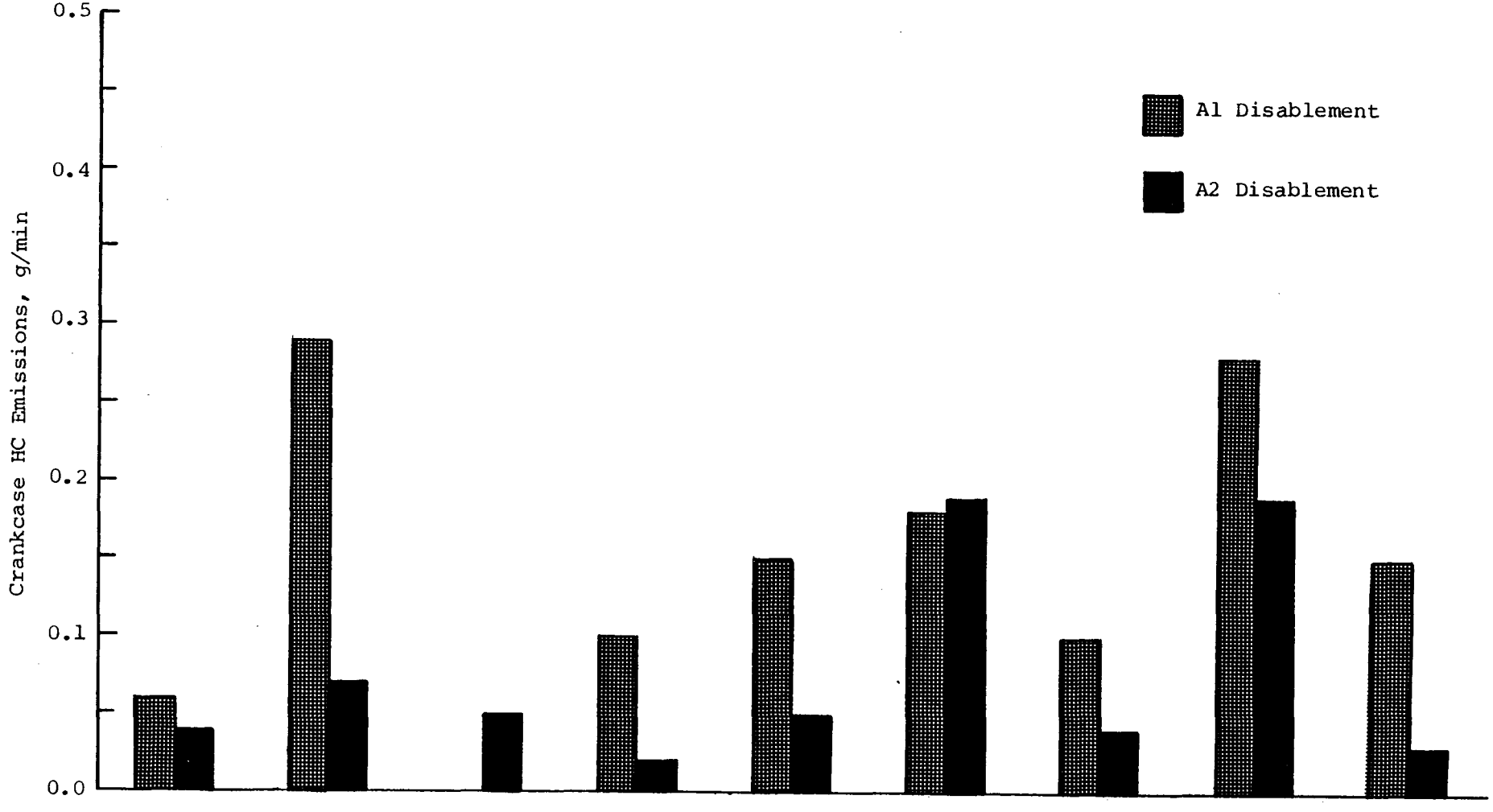
The essentially fixed ratios observed between the HC levels of the individual cycles of the FTP appear not to be functions of engine displacement or engine type or odometer reading, but rather of the combined effect of cycle type and crankcase oil temperature. During the cold transient cycle, the crankcase oil temperature apparently does not increase sufficiently to drive condensed fuel out of the oil and permit HC vapor augmentation of blowby gases. Under this condition, the oil temperature is also cool enough to allow some of the blowby being generated to condense. By contrast, the oil during the cold stabilized cycle is hot enough to both limit blowby condensation and to also degas more efficiently, thus allowing increased HC vapor contribution to the blowby gases. After the 10-minute soak, the scenario described for the cold stabilized cycle is repeated with the hot transient cycle; but this time at a higher oil temperature.

E. Crankcase HC Emissions During Soak

The on-line crankcase HC emissions obtained during the 10-minute soak following the cold stabilized cycle were summarized in Table 4, separately from the 3-bag FTP emissions results. The soak cycle is different from the 3-bag FTP individual cycles because it is run with the engine off. Consequently, units for the HC emissions during soak are g/min and not g/mi, as used with the 3-bag FTP.

Results of the crankcase emissions during soak, using the A1 and A2 disablements, are shown graphically in Figure 12. The HC emissions during the 10-minute soak generally diminished from those at the end of the cold stabilized cycle, to levels close to tunnel background. Generally, the major part of the HC emissions reduction occurred within the first three minutes of the soak.

The highest soak HC emitters using the A1 configuration were the Chevette at 0.29 g/min and the Cougar at 0.28 g/min. Highest HC emitters with the A2 configuration were the Cougar and Skyhawk at 0.19 g/min. Generally, the A2 disablement provided lower soak HC emissions. The Aries and Skyhawk were the only cases for which A2 emissions were higher than A1 emissions. The vehicles with A2 disablement soak emissions less than half those for the A1 disablement were the Chevette, Celica, Monte Carlo, Nova, and Delta 88.



Vehicle	Tercel	Chevette	Aries	Celica	Monte Carlo	Skyhawk	Nova	Cougar	Delta 88
Year	1982	1978	1983	1978	1982	1977	1975	1978	1978
Odometer, mi	32K	44K	21K	52K	21K	57K	58K	46K	69K
Eng.Disp.,$in.^3$	89	98	134	134	229	231	250	351	403
Eng.Type	L4	L4	L4	L4	V6	V6	L6	V8	V8

Figure 12. Crankcase on-line THC emissions of nine test vehicles during 10-minute soak of 3-bag FTP with PCV disablement configurations A1 and A2

REFERENCES

1. Walz, L., "Motor Vehicle Tampering Survey 1982," EPA-330/1-83-001, April 1983.

2. Code of Federal Regulations, Title 40, Chapter 1, Part 86, Subpart B.

3. "Methane Measurement Using Gas Chromatography-SAE J1151," Recommended Practice SAE J1151, 1977.

4. Urban, C.M., "Unregulated Exhaust Emissions from Non-Catalyst Baseline Cars Under Malfunction Conditions," Final Report prepared for the Environmental Protection Agency under Contract 68-03-2884, Task Specifications 4 and 5, May 1981.

APPENDIX A

WORK ASSIGNMENT NO. 19
SCOPE OF WORK AND MODIFICATIONS

Scope of Work

Work Assignment No. 19 to EPA Contract 68-03-3162
"Crankcase Emissions with Disabled PCV Systems"

Introduction

This work assignment is intended to quantify crankcase emissions from gasoline powered passenger vehicles with disabled PCV systems. PCV systems have been found to be disabled with the PCV valve disconnected from its orifice in the valve cover and/or with the fresh air tube to the air cleaner disconnected. This test program will initially test vehicles in two ways: with only the PCV valve disconnected, and with both the PCV valve and fresh air hose disconnected. It is believed that the fresh air hose being disconnected without the PCV valve being disconnected will not cause an emissions change.

In-use vehicles of various engine sizes and model years will be recruited and tested by the contractor. Crankcase emissions will be measured over the FTP cycle through a modified CVS to yield emissions in grams per mile. Emissions will also be measured during the 10 minute hot soak of the FTP, in a separate bag. A heated FID will additionally sample emissions during testing in order to ensure that all HC emissions are accounted for. Methane analysis will also be performed.

Test Apparatus

Crankcase emissions shall be measured through a CVS. A system shall be fabricated by the contractor which will attach to the normal PCV orifice which receives the crankcase emissions. This system shall be made such that it can draw fresh air through it, thus not creating an unrealistic vacuum. The vacuum shall be measured as close to the PCV orifice as possible within this system and maintained at 0.0-0.5 inches of water with the engine off and the CVS on. The PCV valve shall remain attached to its hose going to the carburetor or manifold and be outside of the fabricated system.

A heated FID shall measure HC emissions and methane analysis shall be performed.

Vehicles

The contractor shall obtain test vehicles from any source. A broad mix of vehicle types is required. The contractor shall obtain approval of the vehicle selection by the BTR prior to testing. Requirements are listed below.

1. Ten test vehicles, with no two vehicles identical in make and engine size.

2. Odometers shall be between 20-60K miles for all vehicles with an average of 40K miles.

3. Four to five vehicles shall be 1981 or later model year. The others shall be 1975-1980 model year.

4. Two vehicles each shall have engine sizes in the following categories:

   a. Less than 1.7 liters.
   b. 1.8-2.5 liters.
   c. 2.6-3.9 liters.
   d. 4.0-5.6 liters.
   e. greater than 5.7 liters.

Test Conditions

In both conditions listed below, the PCV valve will be disconnected from its orifice which receives crankcase emissions and be left connected to its hose going to the carburetor or manifold.

1. PCV disconnected, but fresh air hose to air cleaner remains connected.

2. PCV disconnected, and fresh air hose to air cleaner disconnected and plugged at the air cleaner end.

Emissions Tests

Each vehicle shall be tested once at each condition listed above. Only crankcase HC emissions shall be measured.

1. Four Bag FTP

In addition to the normal three bags of the cold start FTP, crankcase emissions shall be collected and measured during the 10 minute soak period in a fourth bag. Emissions from the fourth bag shall be reported separately, i.e., not averaged in with the FTP.

2. Heated FID

A heated FID shall sample emissions during all testing.

3. Methane Analysis

Methane analysis is required for all testing.

Option to Discontinue Testing

After two vehicles have been tested, the contractor shall report the results verbally to the Branch Technical Representative. If crankcase emissions appear to be insignificant at either test condition, the BTR may delete a test condition from further testing or may end the test program altogether.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

MAY 9 1984

Mr. Charles T. Hare
Project Manager
Southwest Research Institute
P.O. Drawer 28510
6220 Culebra Road
San Antonio, TX 78284

Re: Work Assignment No. 19 of Contract 68-03-3162

Dear Mr. Hare:

The purpose of this letter is to provide technical direction to Work Assignment No. 19, titled "Crankcase Emissions with Disabled PCV Systems".

We have determined that there are two disablement modes that could possibly cause crankcase emissions, other than the two listed in the Scope of Work. Please add these two disablement configurations to the other two. Also, we would like to revise the second of the original modes (see below). As before, we may delete one or more of the configurations, depending on the results of the first two or three vehicles. The two new configurations are listed below after the two original ones.

Revised Disablement Configurations To Employ

A. PCV valve disconnected from its orifice which receives crankcase emissions, and still connected to its hose going to carburetor or manifold.

   1. PCV disconnected; fresh air hose to air cleaner connected.

   2. PCV disconnected; fresh air hose to air cleaner completely removed and no part of the system plugged [this is a change].

B. New disablements

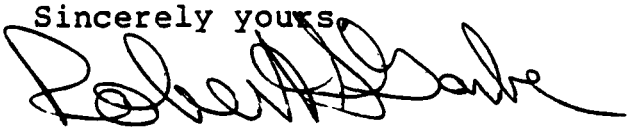
   3. PCV valve remains connected in orifice, but disconnected from hose going to carburetor or manifold; fresh air hose system intact.

4. Fresh air hose to air cleaner completely removed; PCV system properly connected.

These changes are a reemphasis of the effort, but are not an increase to the scope of the program. Adjustments may have to be made in other areas, such as the total number of vehicles, in order to maintain the overall effort. After the first two or three vehicles have been tested, please contact me for review of the effort required.

All other parts of the Scope of Work shall remain the same. If you have any questions, please call.

Sincerely yours,



Robert Garbe, Project Officer
Technical Support Staff

cc: James Bzdusek, Contracts

APPENDIX B

LIST OF AVAILABLE TEST VEHICLES
AS OF JULY, 1984

SOUTHWEST RESEARCH INSTITUTE

INTER-DEPARTMENTAL MEMORANDUM

TO: SwRI and SFBR Staff

FROM: Daniel A. Montalvo - Dept. of Emissions Research

SUBJECT: Crankcase Gas Emissions Tests Using Gasoline Vehicles

DATE: June 20, 1984

We need to measure crankcase gas emissions from gasoline passenger vehicles driven from 20,000 to 60,000 miles using only unleaded gasoline. Model years from 1975 to present are required in the following engine catagories:

a. less than 1.7 liters (<104 cu. in.)
b. 1.8 - 2.5 liters (110-153 cu. in.)
c. 2.6 - 3.9 liters (159-238 cu. in.)
d. 4.0 - 5.6 liters (244-342 cu. in.)
e. greater than 5.7 liters (>348 cu. in.)

The test will require approximately five (5) days. If your car is used, you will be given $75.00, and will also be furnished a car for transportation during its use. Your car will be returned to you with a full tank of gasoline at completion of testing.

If you are willing to participate, please fill in the form and return it to Daniel Montalvo at Building 87. Any questions concerning this request may be directed to Daniel Montalvo at extension 2657.

- -

Yes, I would like to participate in the crankcase gas emissions tests to be conducted at the Department of Emissions Research.

My car has _____ actual miles on the odometer and, to the best of my knowledge, has run only on unleaded fuel.

Year _____ Make _____ Model _____

Engine Displacement _____ l/_____cu. in.

Cylinder No. and Type _____

Name _____ Dept. _____ Telephone No. _____

AVAILABLE TEST VEHICLES

Less than 1.7 liters (<104 cu. in.)

Year	Make	Model	Engine Displacement, ℓ	Cylinder No.	Odometer, Miles
1978	Plymouth	Sapporo	1.6	4	39,000
1978	Chevrolet	Chevette	1.6	4	43,600
1981	Toyota	Tercel	1.5	4	39,120
1981	Ford	Escort	1.6	4	58,000
1981	Plymouth	TC3	1.7	4	70,200
1981	Plymouth	Horizon	1.7	4	58,731
1981	Honda	Civic	1.3	4	46,000
1981	Toyota	Tercel	1.5	4	26,400
1981	Chevrolet	Chevette	1.6	4	27,426
1981	Dodge	Colt	1.4	4	38,000
1981	Mercury	Lynx	1.6	4	46,599
1981	Honda	Civic	1.5	4	67,000
1982	Ford	Escort	1.6	4	34,372
1982	Honda	Prelude	1.7	4	25,300
1982	Datsun	Sentra	1.5	4	40,000
1982	Toyota	Tercel	1.5	4	31,867

1.8-2.5 liters (110-153 cu. in.)

1978	Volvo	244 DL	2.1	4	45,000
1978	Toyota	Celica	2.2	4	51,320
1978	Toyota	Celica	2.2	4	44,000
1979	Honda	Accord	1.8	4	92,787
1979	AMC	Spirit	2.0	4	45,873
1980	Toyota	Celica GT	2.2	4	52,093
1980	Chevrolet	Monza	2.5	4	41,239
1980	Chevrolet	Monza	2.0	4	58,260
1980	Ford	Mustang II	2.3	4	31,000
1980	Honda	Accord LX	1.8	4	43,467
1980	Buick	Skyhawk	2.5	4	56,100
1980	Mercury	Capri	2.3	4	41,000

AVAILABLE TEST VEHICLES

1.8-2.5 liters (110-153 cu. in.) (Cont'd.)

Year	Make	Model	Engine Displacement, ℓ	Cylinder No.	Odometer, Miles
1980	Honda	Accord	1.8	4	53,470
1981	Olds.	Omega	2.5	4	22,000
1981	Honda	Accord	1.8	4	29,102
1981	Volkswagen	Rabbit	1.7	4	34,482
1982	Chevrolet	Cavalier	1.8	4	28,700
1982	Peugeot	505	2.0	4	23,000
1982	Dodge	Charger	2.2	4	42,400
1982	Mazda	626	2.0	4	52,340
1982	Toyota	Corona	2.2	4	55,000
1982	Toyota	Corolla	1.8	4	38,933
1982	Toyota	Corolla	1.8	4	27,382
1982	Chevrolet	Cavalier	1.8	4	20,060
1983	Datsun	Maxima	2.4	6	23,261
1983	Toyota	Corolla	1.8	4	30,000
1983	Dodge	Aries	2.2	4	19,300
1983	Honda	Accord LX	1.8	4	25,100

2.6-3.9 liters (159-238 cu. in.)

1977	Buick	Skyhawk	3.8	6	56,900
1978	Pontiac	Grand Prix	3.8	6	64,000
1978	Ford	Fairmont	3.3	6	57,976
1978	Pontiac	Sunbird	3.8	6	54,321
1980	Pontiac	Grand Prix	3.8	6	56,559
1980	Ford	Fairmont	3.3	6	22,000
1981	Dodge	Challenger	2.6	4	38,000
1981	Dodge	Challenger	2.6	4	41,860
1981	Ford	Fairmont	3.3	6	20,000
1981	Pontiac	Grand Prix	3.8	6	55,935
1981	Pontiac	La Mans	3.8	6	40,415
1981	Chevrolet	Monte Carlo	3.8	6	20,850

AVAILABLE TEST VEHICLES

2.6-3.9 liters (159-238 cu. in.) (Cont'd.)

Year	Make	Model	Engine Displacement, ℓ	Cylinder No.	Odometer, Miles
1981	Mercury	Zephyr	3.3	6	27,788
1982	Pontiac	Bonneville	3.8	6	22,808
1982	Plymouth	Gran Fury	3.7	6	21,200
1982	Chevrolet	Celebrity	2.8	6	34,310
1983	Oldsmobile	Cutlass Sup.	3.8	6	22,097
1983	Toyota	Cressida	2.8	6	31,163

4.0-5.6 liters (244-343 cu. in.)

1975	Chevrolet	Nova	4.1	6	57,700
1975	Chevrolet	Nova	4.5	8	52,200
1977	Chevrolet	Impala	5.0	8	88,000
1978	Mercury	Zephyr	5.0	8	56,538
1978	Pontiac	Grand AM	4.9	8	61,821
1978	Pontiac	Phoenix	5.0	8	60,000
1978	Pontiac	Grand Prix	5.0	8	51,800
1978	Pontiac	Grand Prix	4.9	8	44,778
1978	Chevrolet	Malibu	5.0	8	42,000
1978	Pontiac	Firebird	5.0	8	65,000
1979	Oldsmobile	Salon	4.3	8	61,668
1979	AMC	DL	4.2	6	33,222
1979	Ford	LTD	5.0	8	56,216
1981	Pontiac	Catalina	5.0	8	26,850
1982	Oldsmobile	Cutlass	4.3	8	39,800
1982	Oldsmobile	Delta 88	5.0	8	36,243
1982	Chevrolet	Monte Carlo	4.4	8	34,640
1983	Oldsmobile	Custom Cruiser	5.0	8	23,645

AVAILABLE TEST VEHICLES

Greater than 5.7 liters (>348 cu. in.)

Year	Make	Model	Engine Displacement, ℓ	Cylinder No.	Odometer, Miles
1975	Pontiac	Gran Prix	7.5	8	135,000
1976	Oldsmobile	Delta 88	7.5	8	114,777
1976	Chevrolet	Monte Carlo	5.7	8	60,000
1977	Chevrolet	Camaro	5.7	8	102,000
1977	Mercury	Grand Marquis	7.5	8	65,000
1978	Mercury	Cougar	5.8	8	44,820
1978	Oldsmobile	Delta 88	6.6	8	63,000
1978	Chevrolet	Caprice	5.7	8	45,000
1978	Cadillac	Sedan Deville	7.0	8	59,432
1979	Oldsmobile	Delta 88	5.7	8	66,315

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report describes the laboratory testing of nine in-use light-duty gasoline passenger cars using up to four PCV disablement configurations. The nine vehicles included 1975 to 1983 model years, with odometer readings generally between 20,000 and 60,000 miles. No two vehicles were identical in make and engine type, and engine displacements ranged from 89 to 403 in.^{3}. The vehicles were tested over the 1975 Federal Test Procedure, with sampling for crankcase HC conducted during each individual cycle of the 3-bag FTP and during the 10-minute hot soak. Emissions of crankcase HC are provided in g/mi for the 3-bag FTP, and in g/min for the 10-minute soak.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Blowby Crankcase PCV Disabled PCV Gasoline Engine	Gasoline Engine PCV System Crankcase HC Emissions Crankcase Blowby Light-Duty Vehicle Crankcase Emissions	

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